Methodology for the determination of CERES Edition 3 Calibration Parameters

CERES Instrument Working Group
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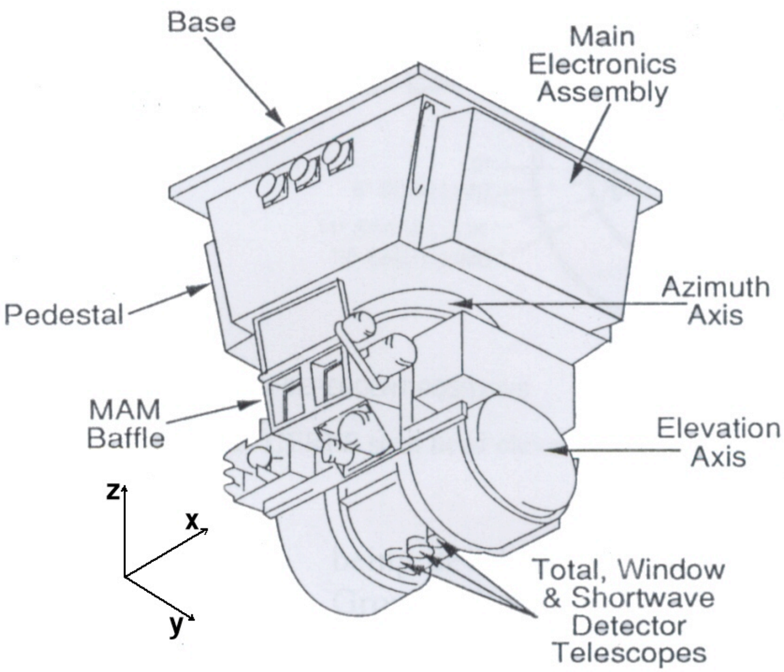
Contributors: Norman Loeb, Costy Loukachine, Bruce Wielicki

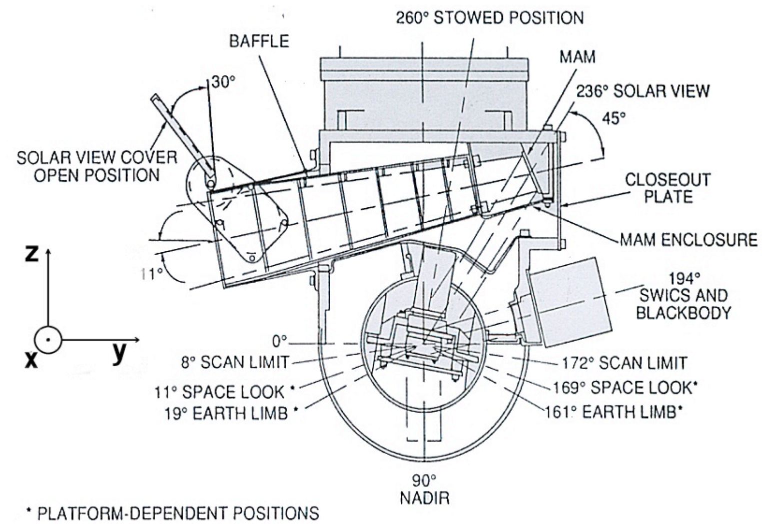
- Introduction: Desired ERB data product measurement stability stretches CERES design specification
- Improved model uses Ed1-CV matched to SSF-MODIS information used to identify scenes and estimate spectra
- Deep convective cloud albedo used to derive SW gain changes rather than SWICS in order to increase stability
- Iterative SW darkening model is tuned using allsky and clear ocean direct compare
- Initial results very promising for Aqua (Terra Model still being tuned)
- Re-analysis of 3 channel: suggests adjustments SW total channel response that result in an increase in CERES daytime LW
- Future considerations and topics for discussion

Ohring et al (2005) suggests that ERB measurement stability needs to reach 0.3% per decade

This is near to an order of magnitude greater than CERES instrument design specification stability (note: not data products)

Original CERES SW calibration principal, like ERBE, intended to use onboard Lamps to detect ground-flight gain shifts. Stability was to be obtained using solar reflecting MAMs





MAMs did not meet specifications, Rev1 stability depends on SWICS lamps and requires xtrack instrument not to undergo spectral darkening (either or both may explain Aqua divergence from Terra)

Onboard lamp output is unlikely to be stable to 0.3%/decade, hence the new model uses MODIS to find the thickest, coldest and most uniform clouds in the tropics referred to as Deep Convective Clouds (DCC). The diagnostic DCC filtered albedo to replace MAM stability metric is then found:

DCCalb = frad(ed1cv)*{flx(ssf)/ufrad(ssf)} * DM(sz)/Fs

DCC criteria: Tau > 50, Temp < 205K, Imager stddev < 3%

Un-filtered Radiance is the data product and should be unaffected by changes in calibration:

$$L = \int_0^\infty L(\lambda) d\lambda$$

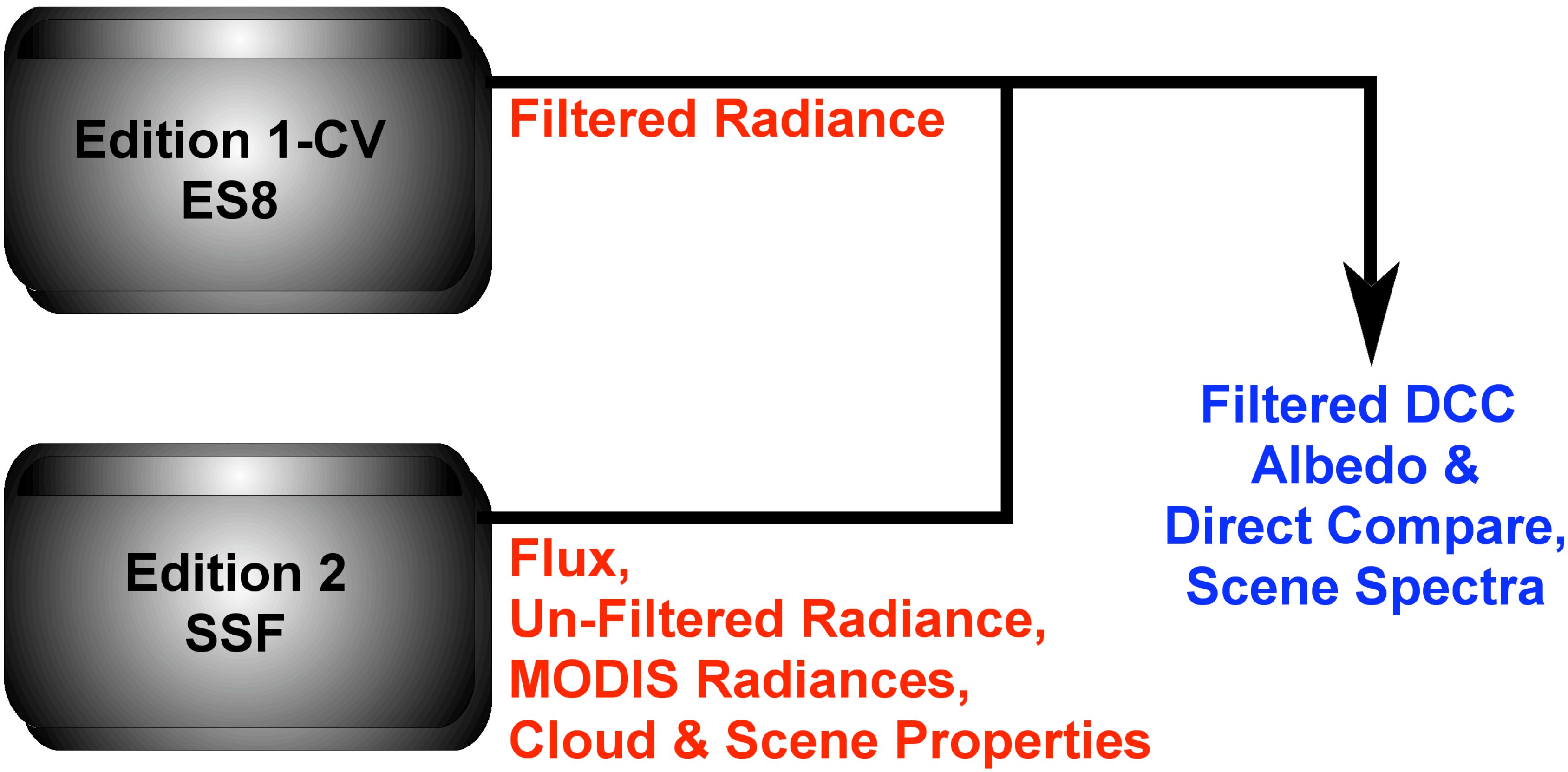
Filtered Radiance is a measurement affected by changes in Earth spectrum, spectral response and gain:

$$LF = G \times \int_0^\infty r(\lambda) L(\lambda) d\lambda$$

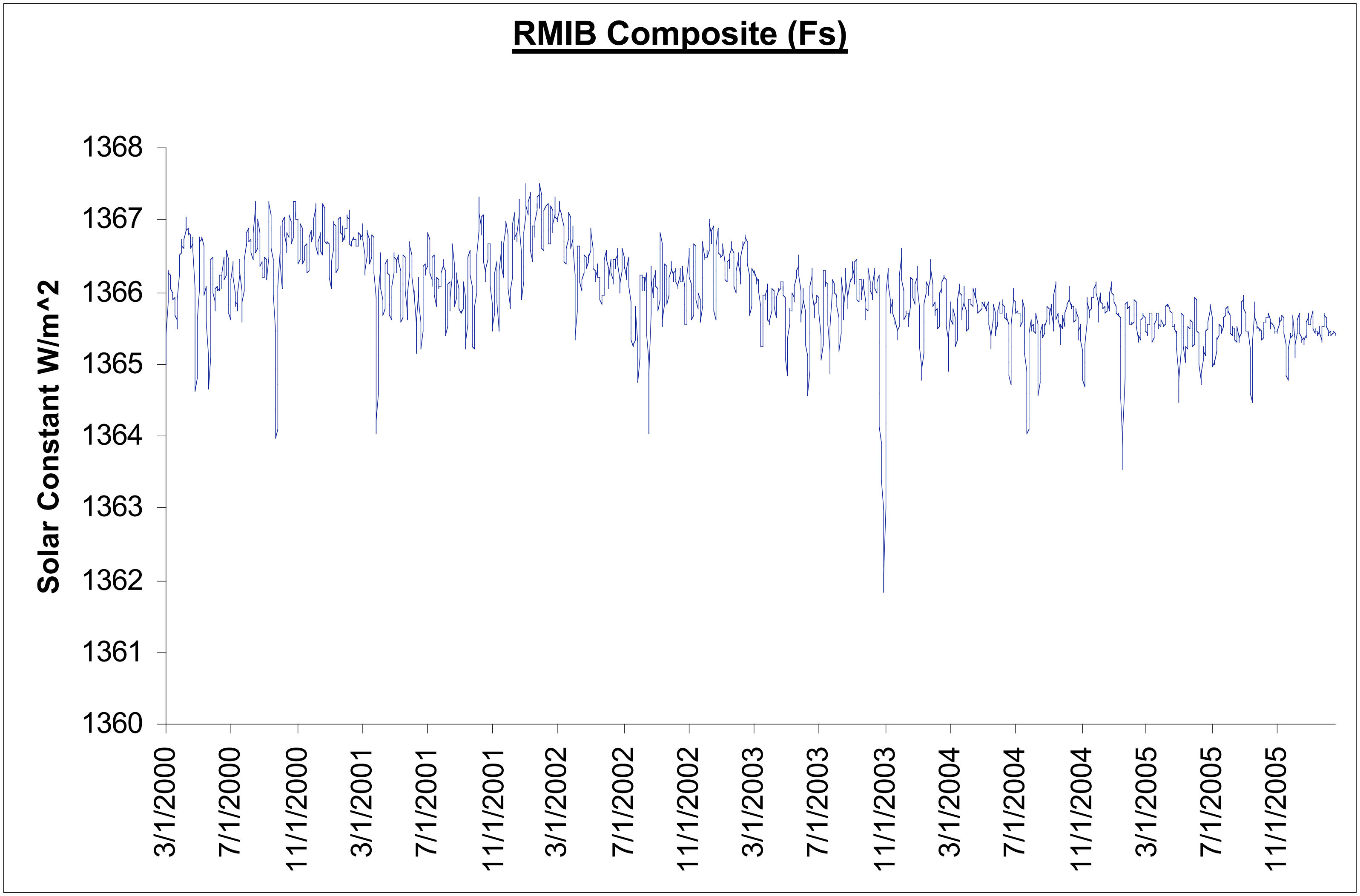
Production of un-filtered product 'L' relies on in-flight calibration to determine gain change 'G' and updated spectral responses to correctly un-filter using coefficient 'f':

$$f = \frac{\int_0^\infty r(\lambda) L(\lambda) d\lambda}{\int_0^\infty L(\lambda) d\lambda} \qquad L = \frac{LF}{G \times f}$$

In order to use filtered radiance as a diagnostic, a run of CERES ES8 data was generated with fixed calibration and production code (Edition 1-CV). Filtered radiance footprints are then matched with SSF information on ADMs, scene type & MODIS radiances.



DCCalb derived as: **frad(ed1cv)*{flx(ssf)/ufrad(ssf)} * DM(sz)/Fs**



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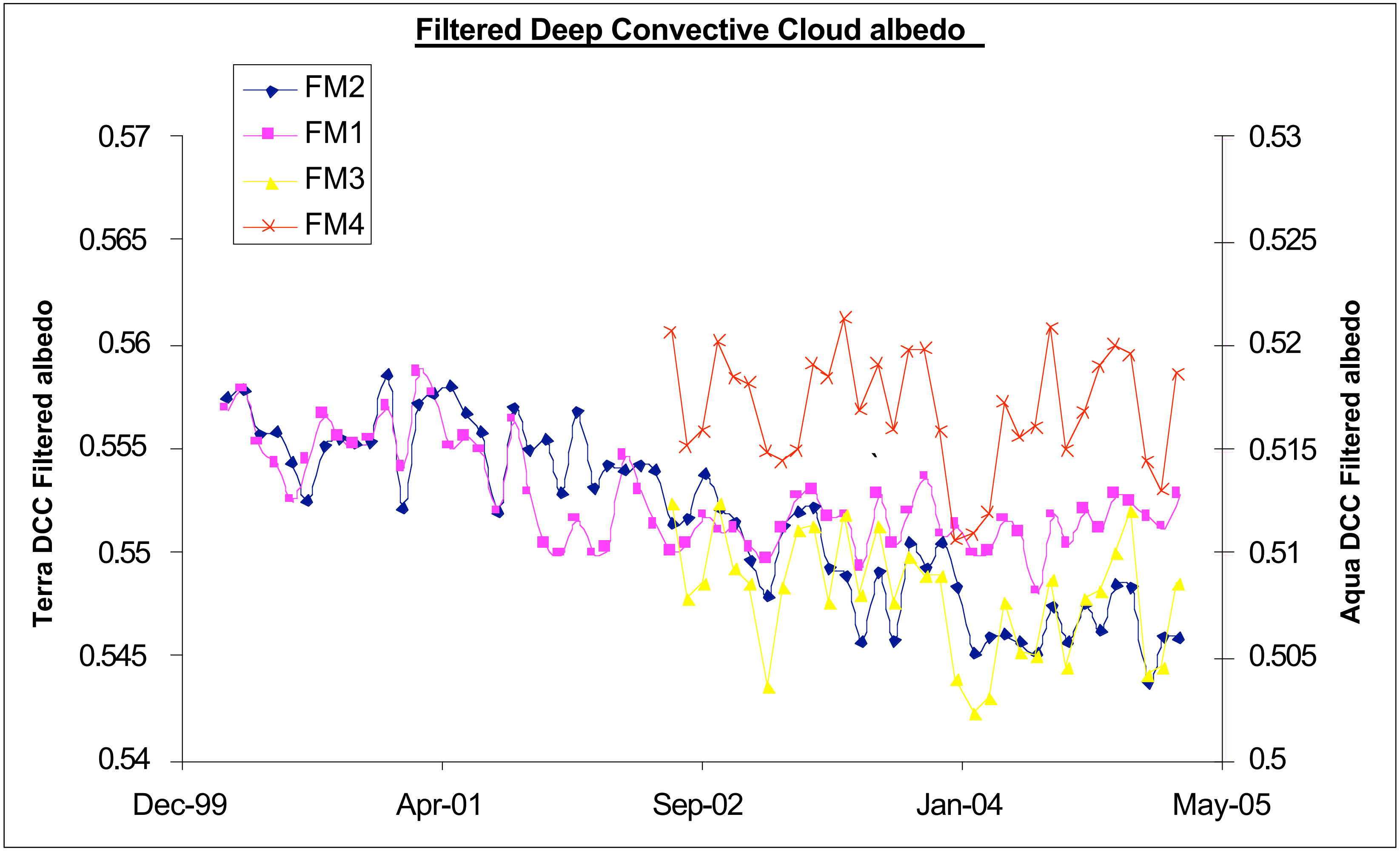
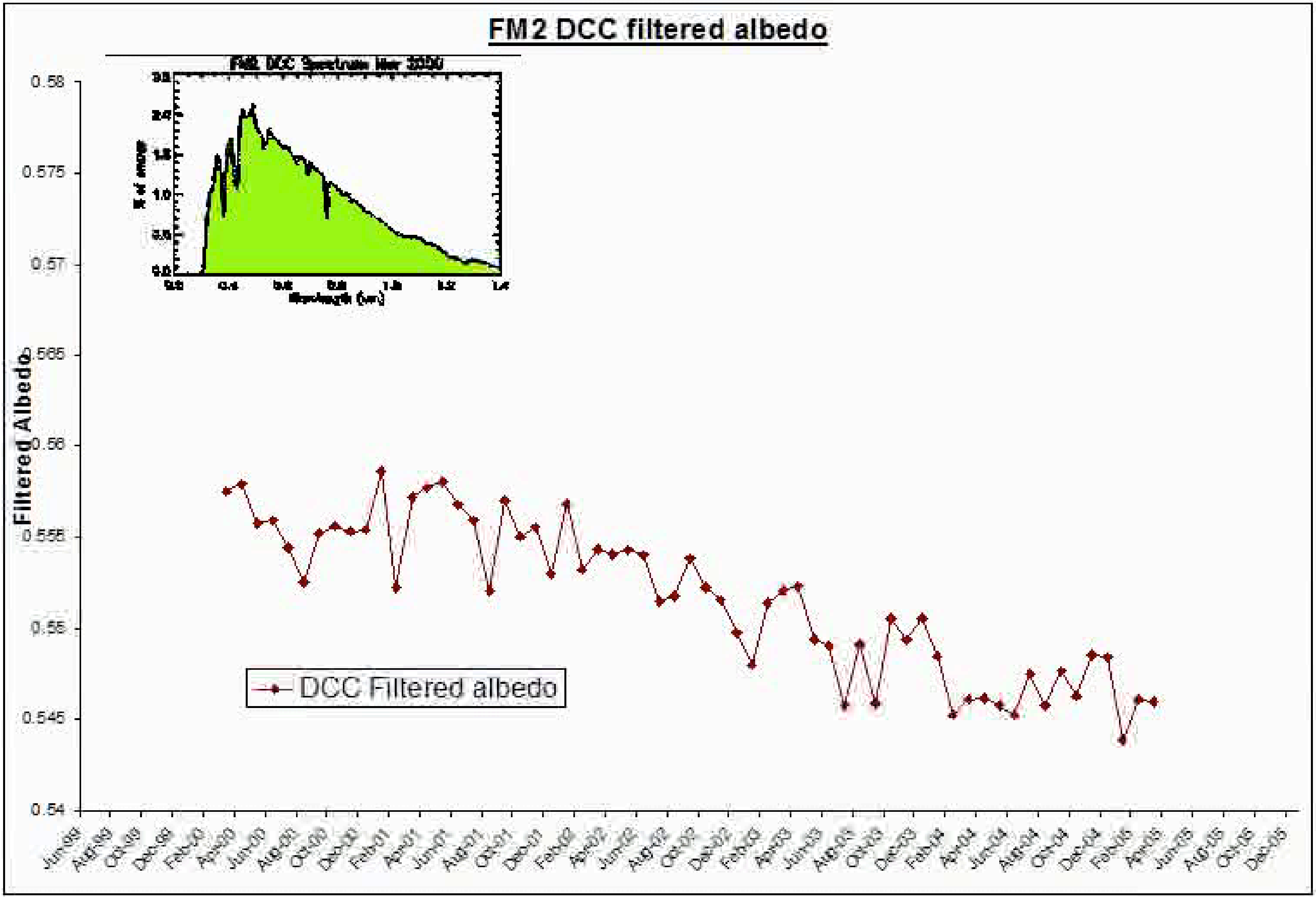
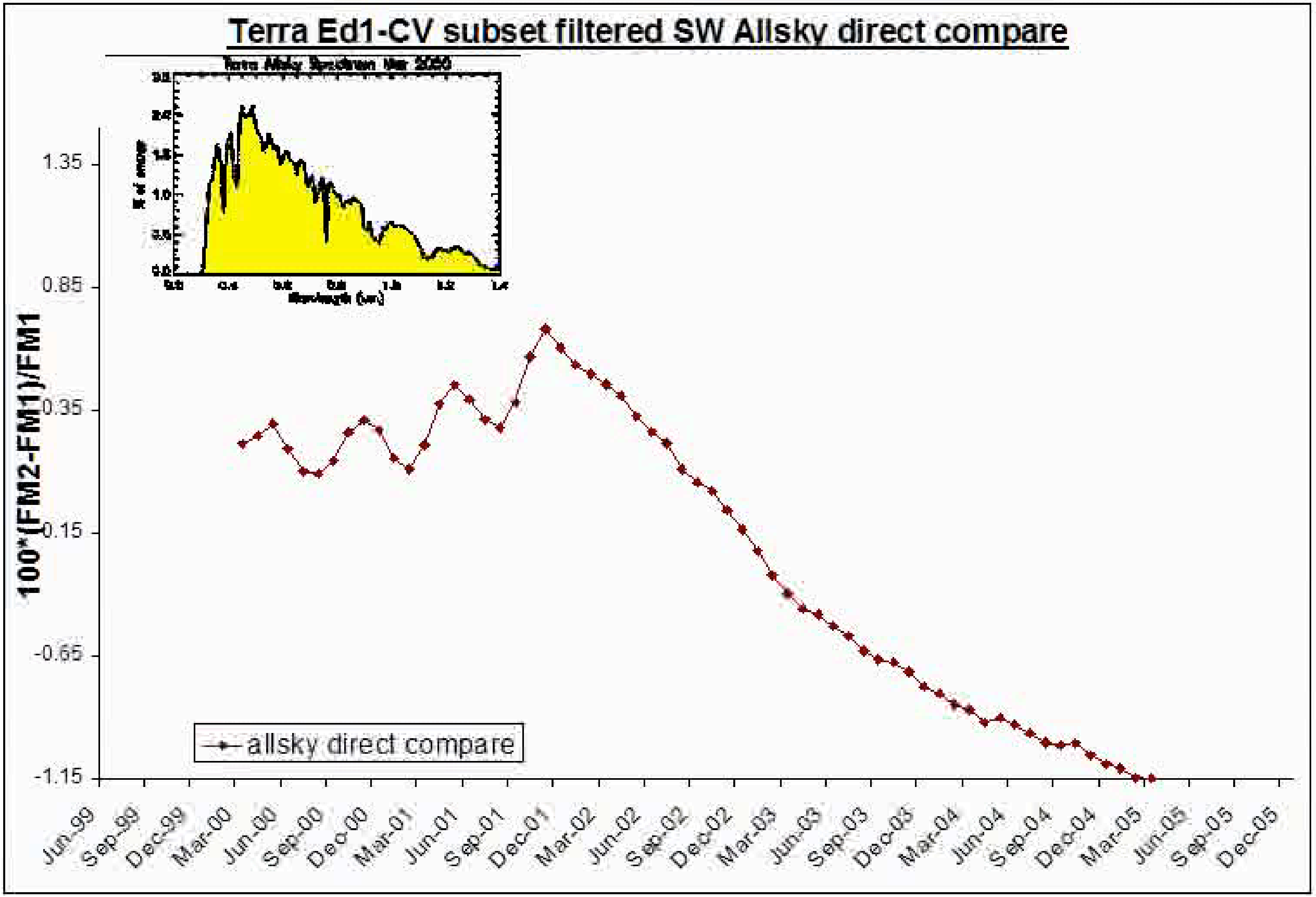




FM2 DCC filtered albedo
FM2 DCC Spectrum Mar 2000
Filtered Albedo
DCC Filtered albedo



Terra Ed1-CV subset filtered SW Allsky direct compare
100*(FM2-FM1)/FM1
1.35
0.85
0.35
-0.15
-0.65
-1.15
allsky direct compare
Jun-99
Sep-99
Dec-99
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
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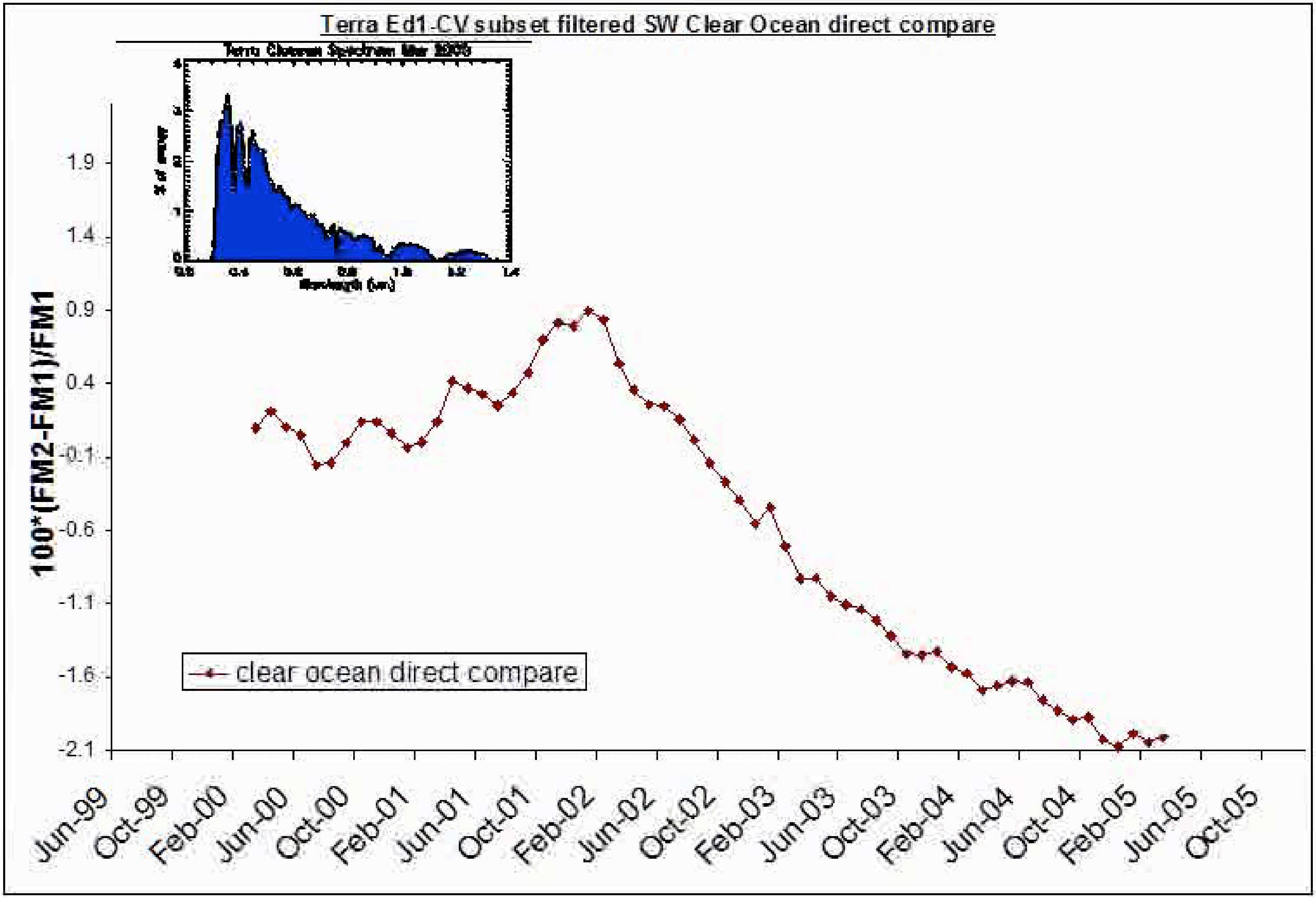
Dec-04
Mar-05
Jun-05
Sep-05
Dec-05


Terra Ed1-CV subset filtered SW Clear Ocean direct compare
100*(FM2-FM1)/FM1
1.9
1.4
0.9
0.4
-0.1
-0.6
-1.1
-1.6
-2.1
clear ocean direct compare
Jun-99
Oct-99
Feb-00
Jun-00
Oct-00
Feb-01
Jun-01
Oct-01
Feb-02
Jun-02
Oct-02
Feb-03
Jun-03
Oct-03
Feb-04
Jun-04
Oct-04
Feb-05
Jun-05
Oct-05

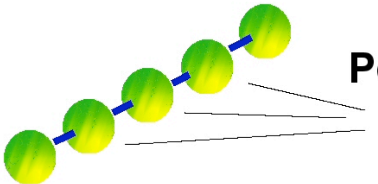
Onboard lamp output is unlikely to be stable to 0.3%/decade, hence the new model uses DCC filtered albedo to derive gain

$$
\begin{aligned}
Gain &= \frac{counts}{frad} \\
&= \frac{DCCalb}{\int_0^\infty L^{DCC}(\lambda) r_{sw}(\lambda) d\lambda}
\end{aligned}
$$

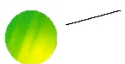
Where DCC spectra are normilised each month:

$$\int_0^\infty L^{DCC}(\lambda) d\lambda = 1.0$$

Contaminant Assumptions

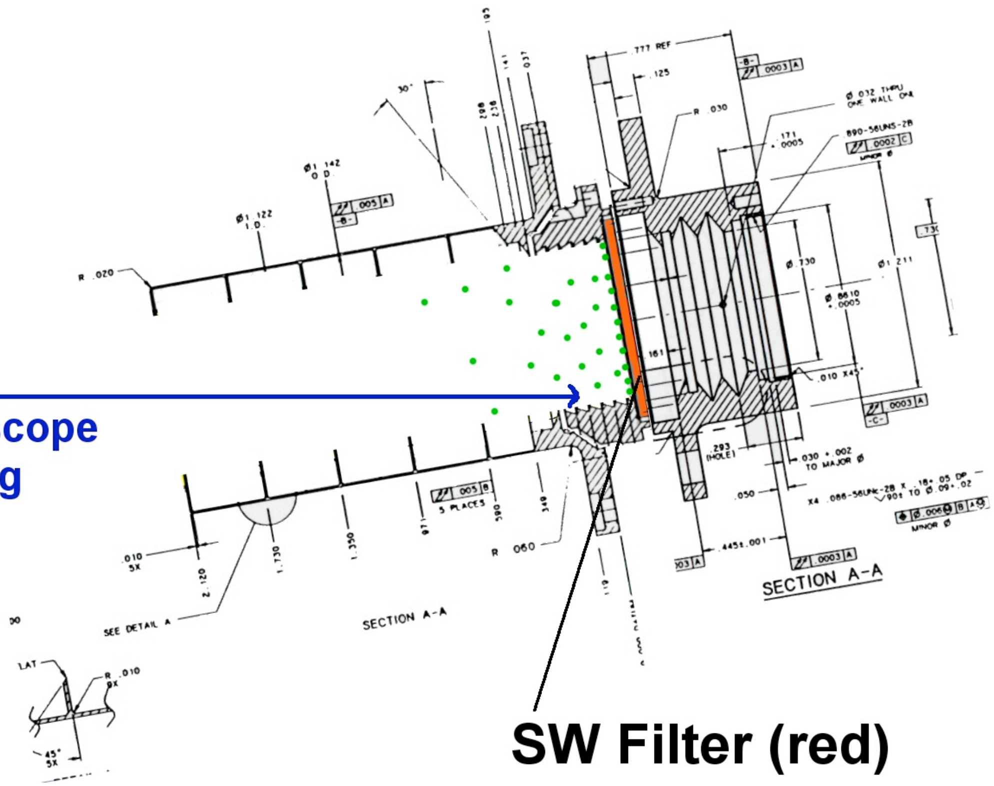


Polymerized contaminant molecules in absorbing chain, category 'B'



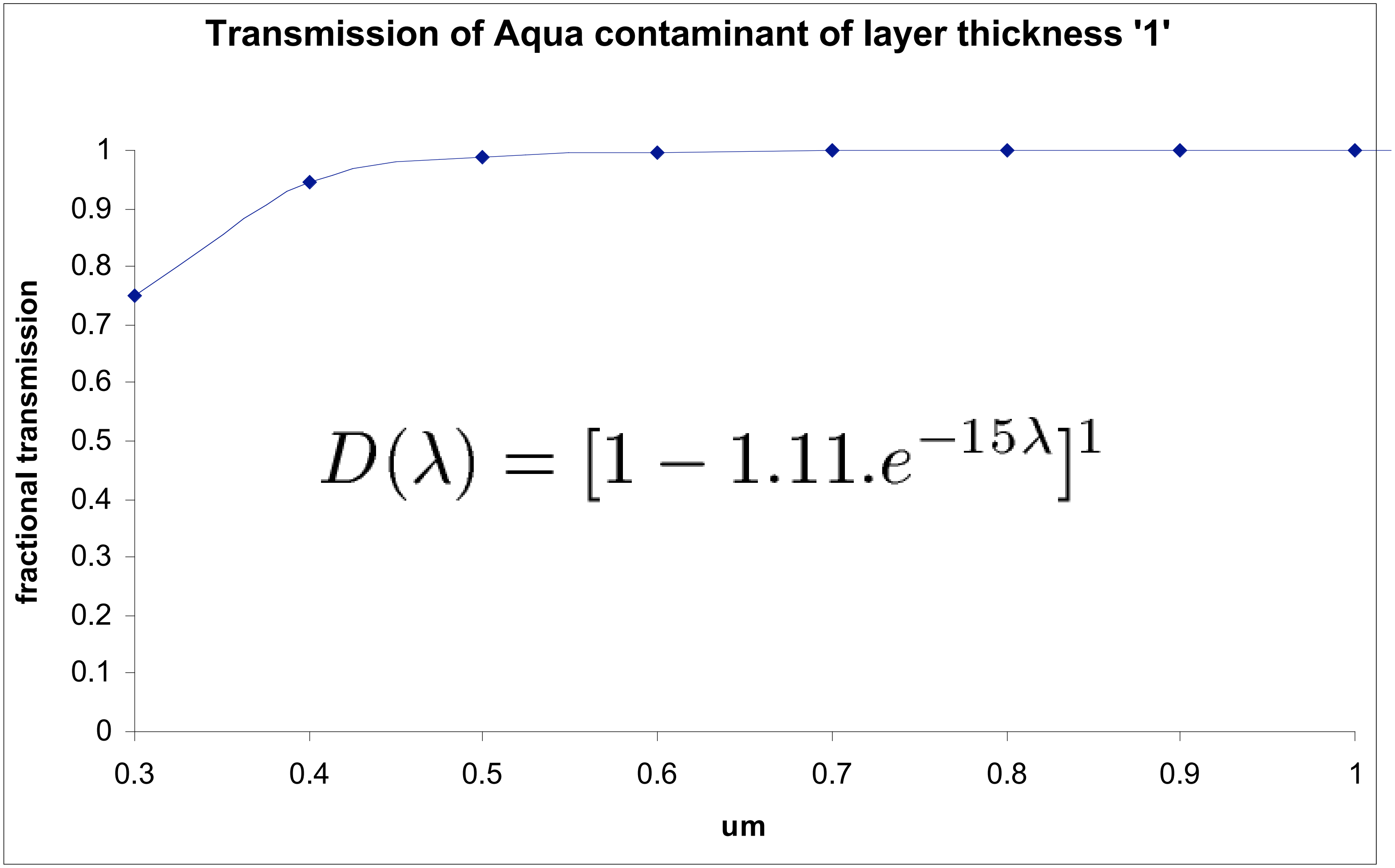
Un-polymerized 'solo' contaminant molecule category 'A' (non-absorbing)

Space bound particles enter telescope when in RAM direction, freeing contaminant molecules to be fixed to filter by Earth UV

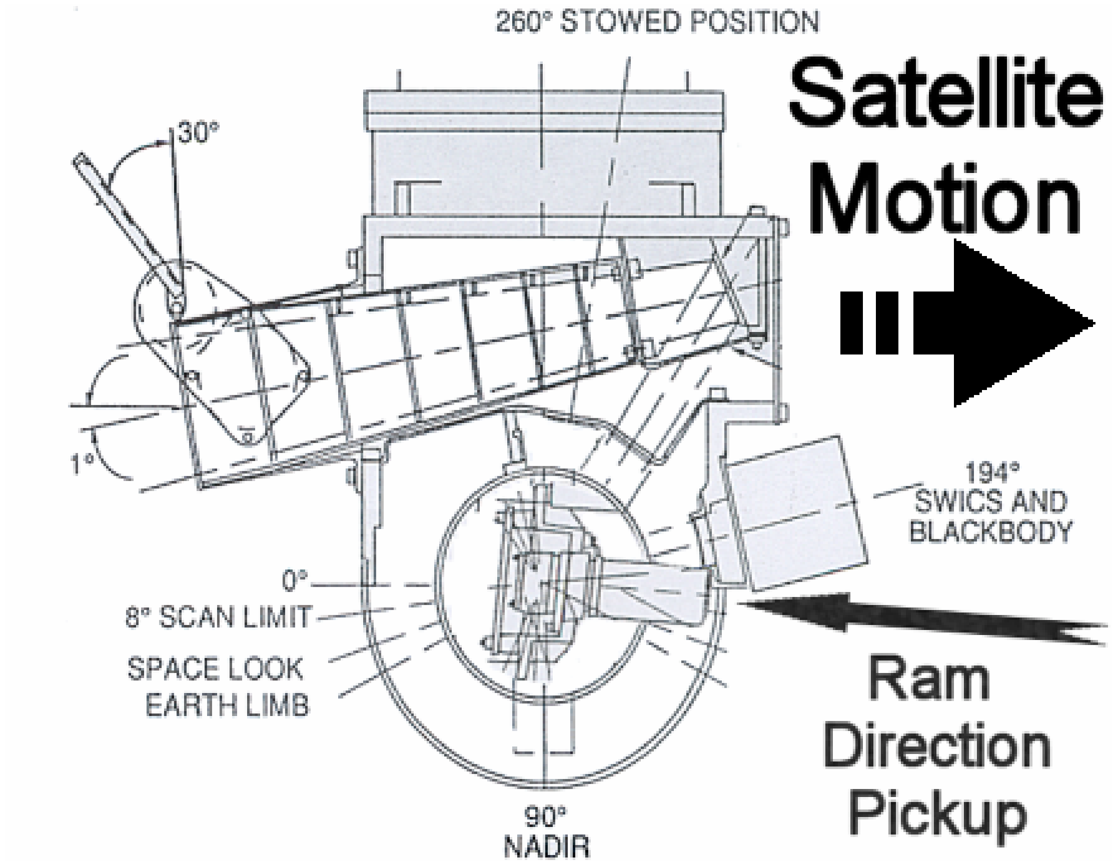


SW Filter (red)

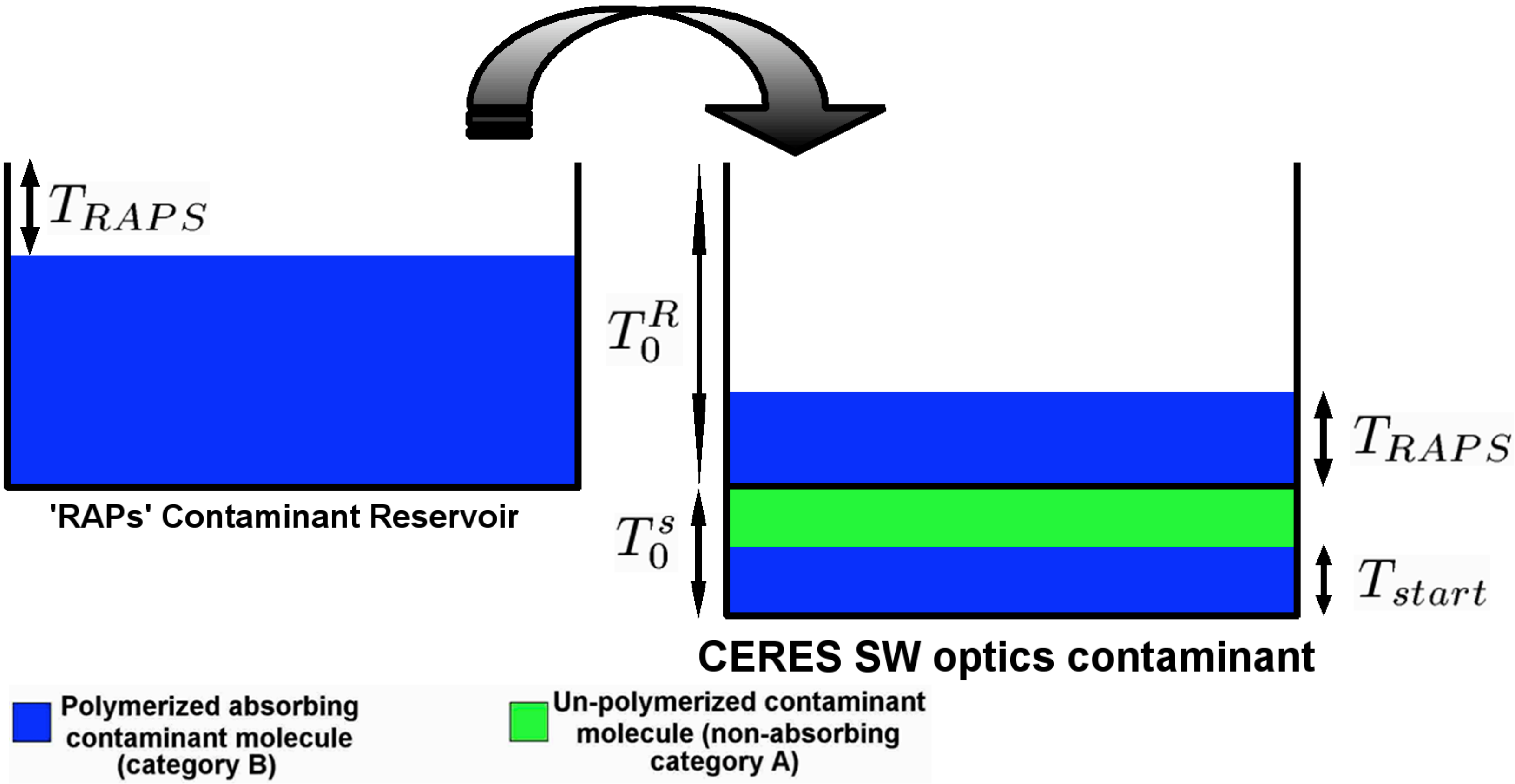
Assume contaminant B thickness of ‘1’ has transmission given by:



In order for contaminants to interact with space bound particulates and arrive at the filter the telescope would need to be looking in the RAM direction (ocurring only in RAPs mode)



Molecule B transport only occurs in RAPs mode



$$\frac{dT_{start}}{dt} = a_s[T_0^s - T_{start}] \qquad \frac{dT_{RAPS}}{dt_R} = a_R[T_0^R - T_{RAPS}]$$

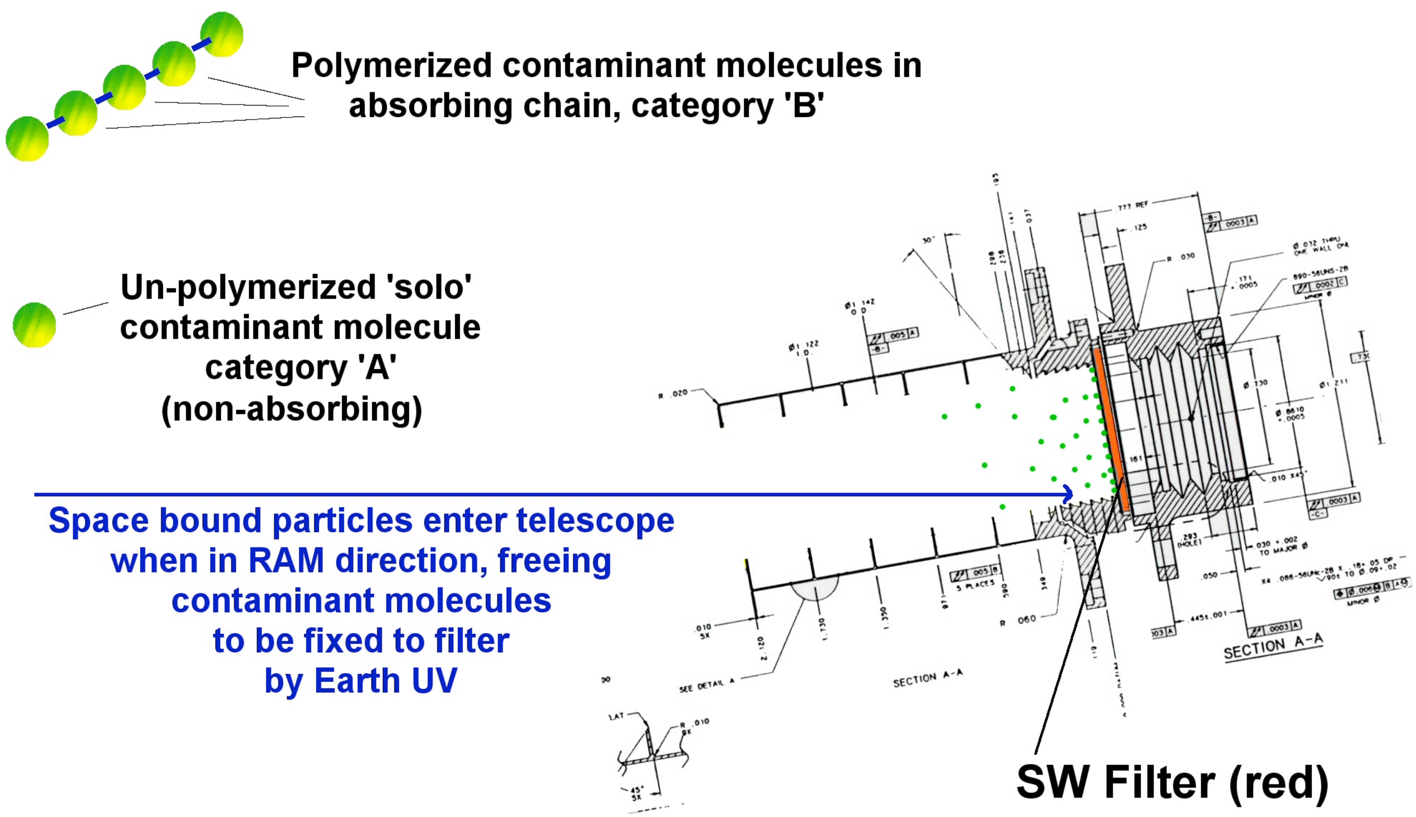
Hence to calculate gain we need the darkening model to tell us the spectral response degradation D(_) in each month

$$D(\lambda) = [1 - A.e^{-\alpha\lambda}]^{T_{start}+T_{RAPS}}$$

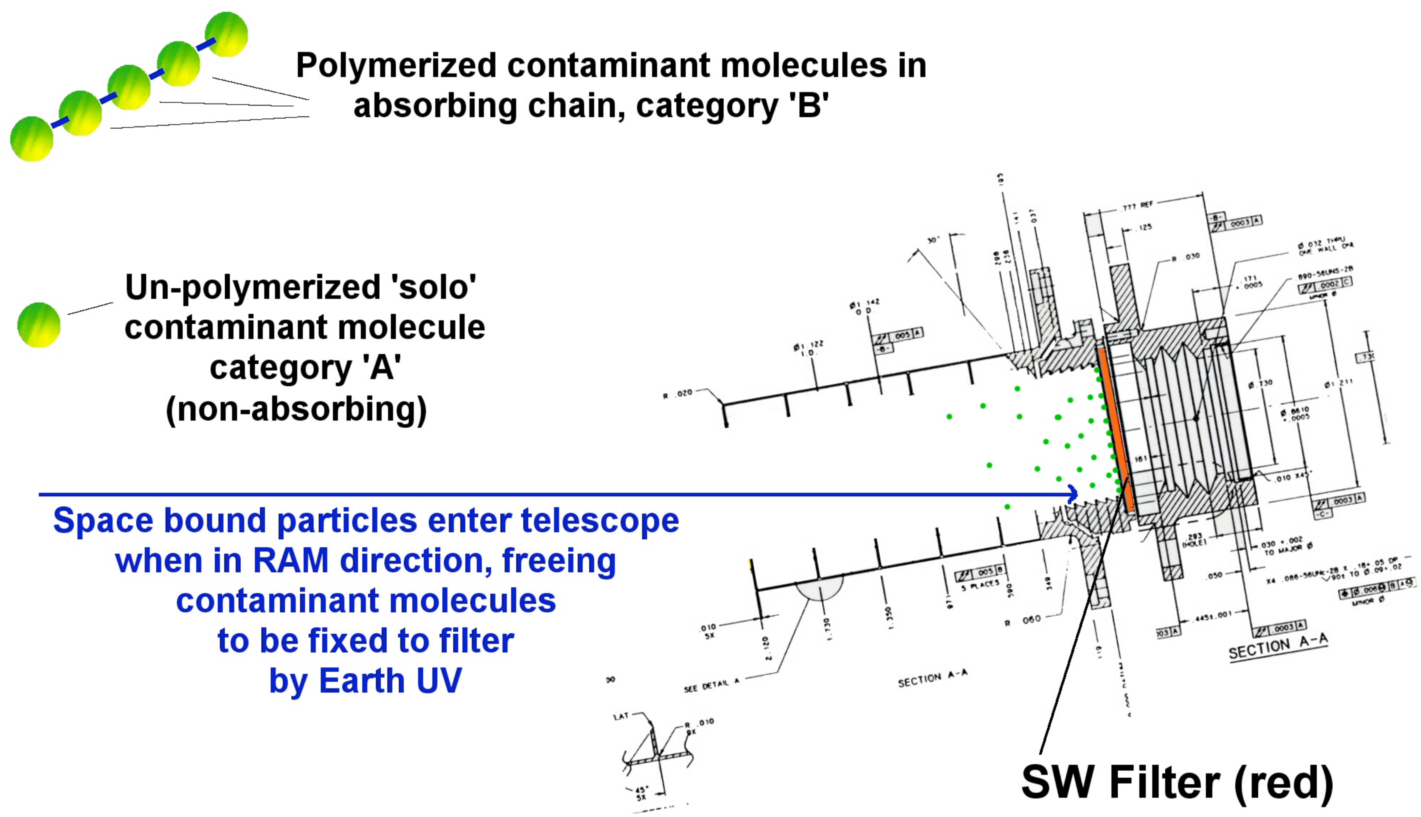
$$T_{start} = T_0^s[1 - e^{-a_s t}]$$

$$T_{RAPS} = T_0^R[1 - e^{-a_R t_R}]$$

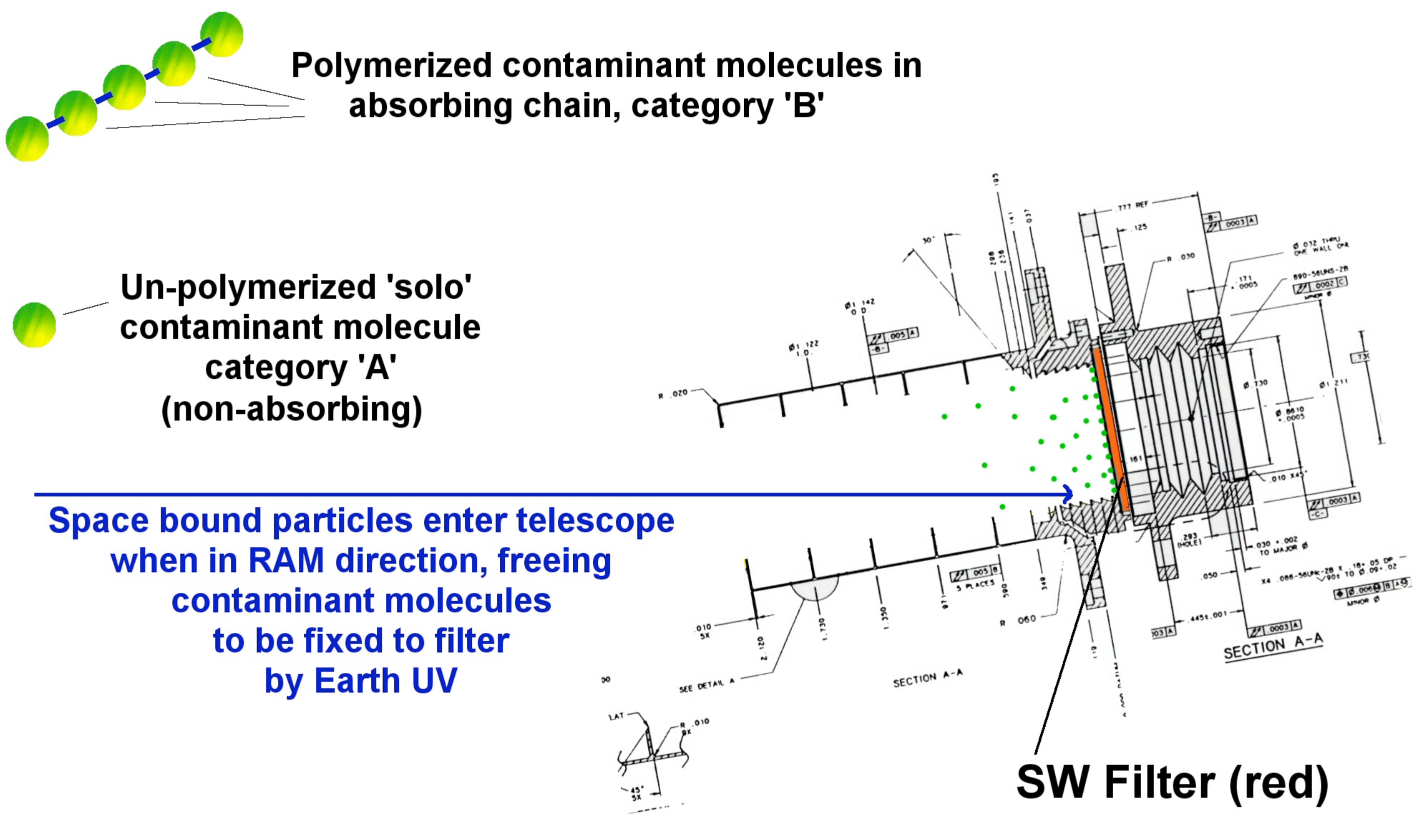
Assume when in RAPS mode atomic oxygen has the capability of depositing 0.9 thickness of molecule B on SW filter throughout mission. Rate of arrival decays with time constant 650 days.



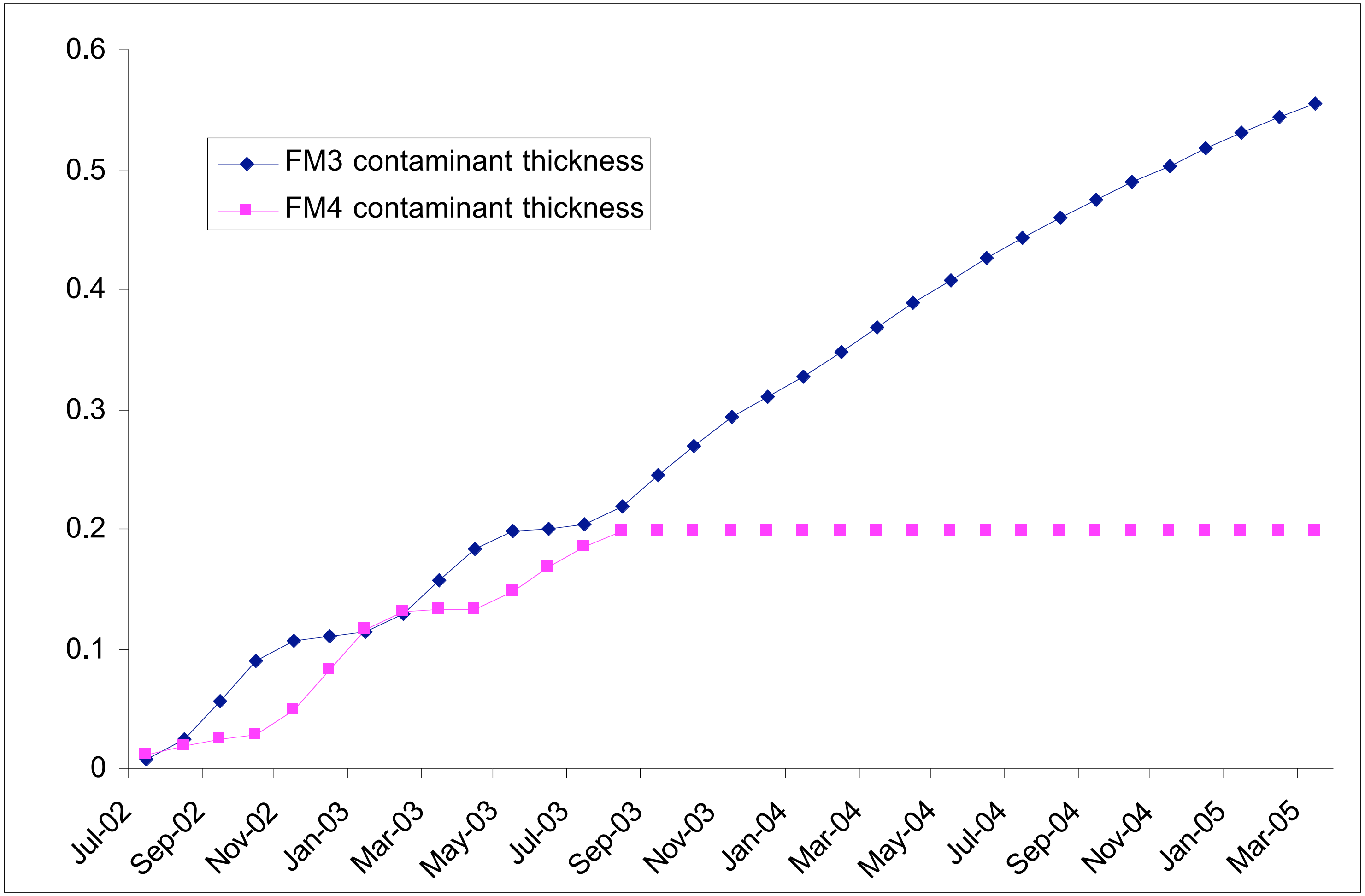
At mission start FM3 was already contaminated with 0.2 thickness of non-absorbing contaminant A. Due to continued Earth UV exposure these category A molecules turn into category B absorbers with time constant of 650 days.



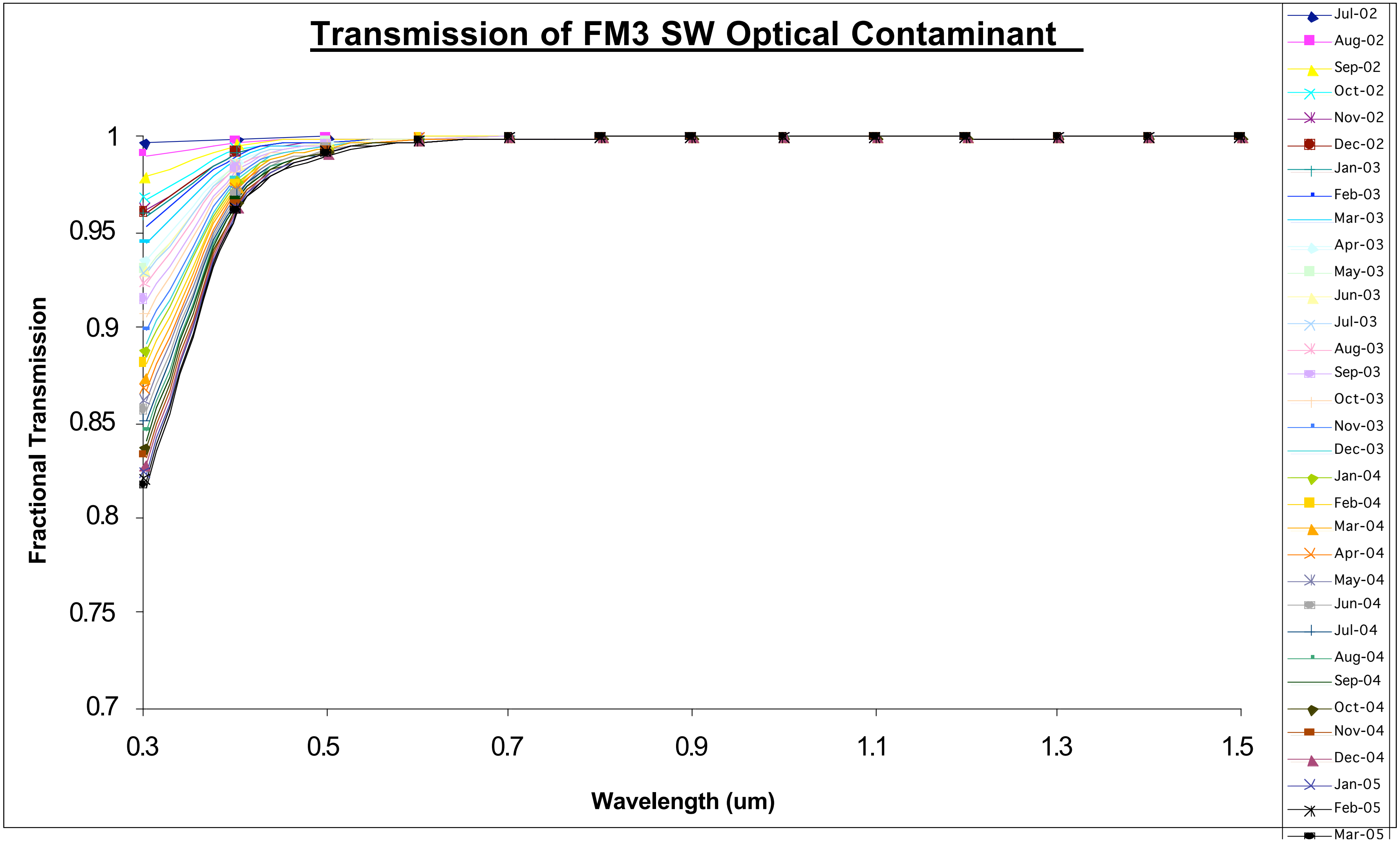
At mission start FM4 was already contaminated with 0.07 thickness of non-absorbing contaminant A. Due to continued Earth UV exposure these category A molecules turn into category B absorbers with time constant of 135 days.



Hence the thickness of category B absorbing molecules on Aqua is:



The Edition 3 change to the spectral response D(_) is hence found:



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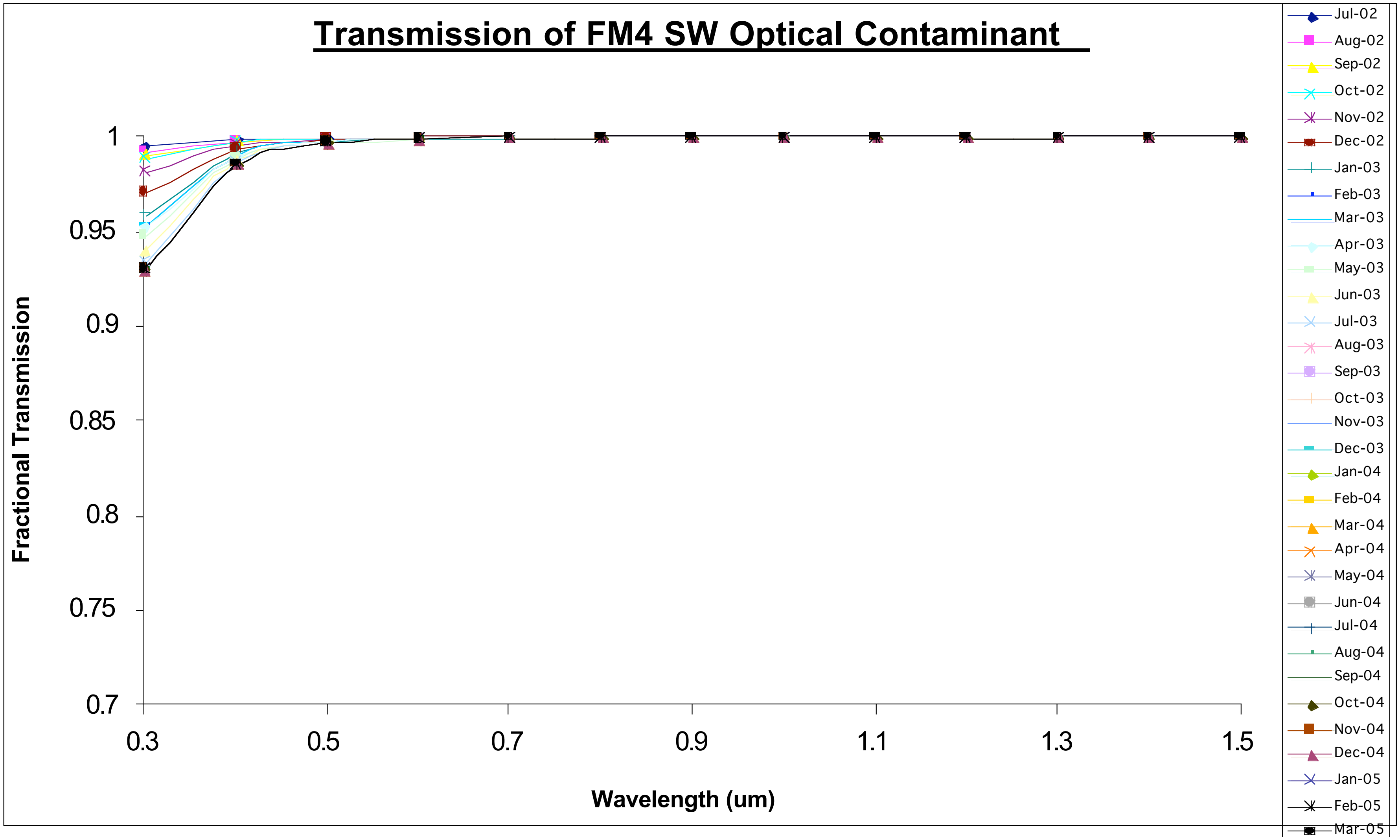


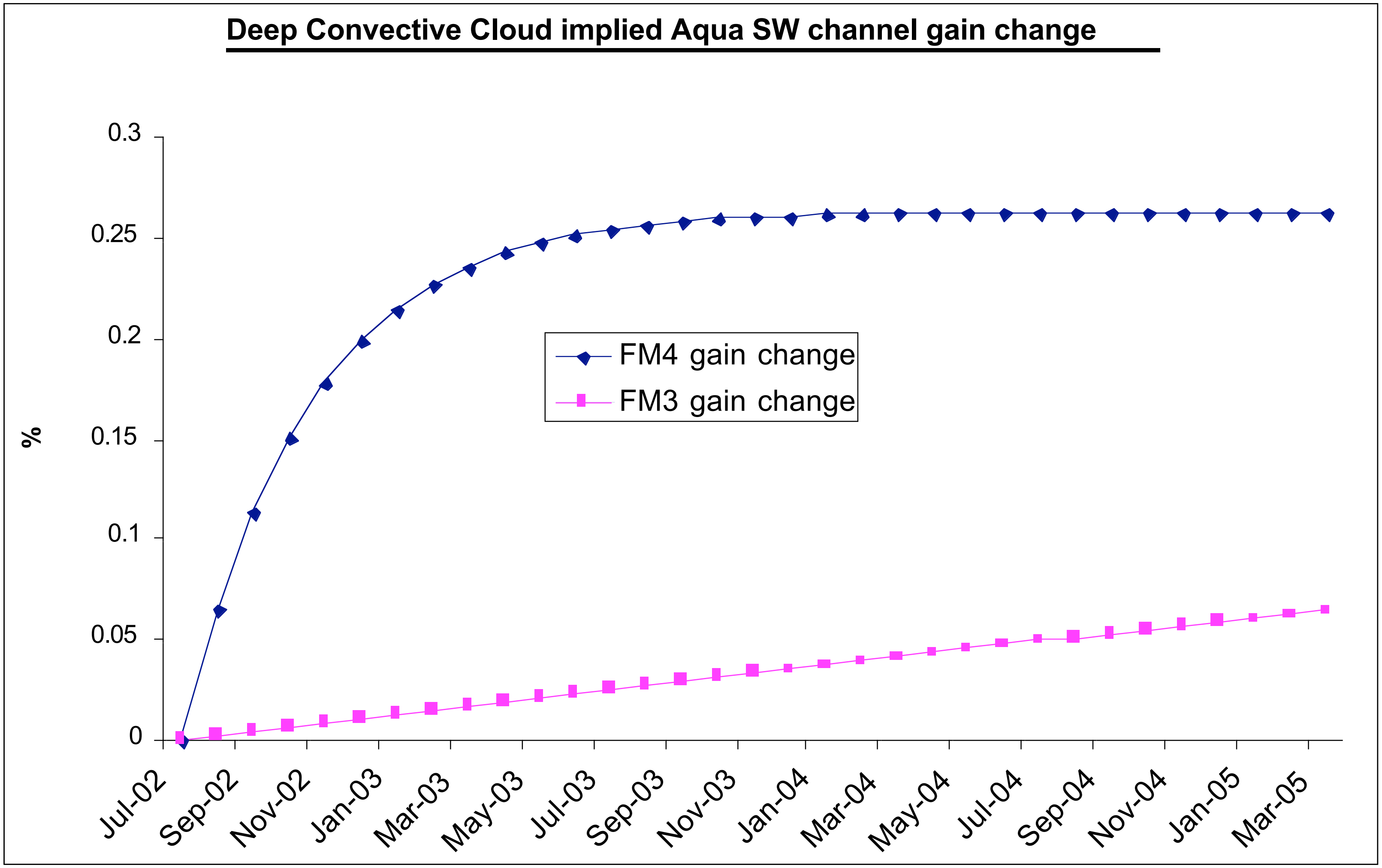
Hence using the model spectral response:

$$r_{sw}(\lambda) = D(\lambda).R^0_{sw}(\lambda)$$

And using the filtered DCC albedo we can now measure drifts in the instrument gain:

$$\begin{aligned} Gain &= \frac{counts}{frad} \\ &= \frac{DCCalb}{\int_0^\infty L^{DCC}(\lambda) r_{sw}(\lambda) d\lambda} \end{aligned}$$

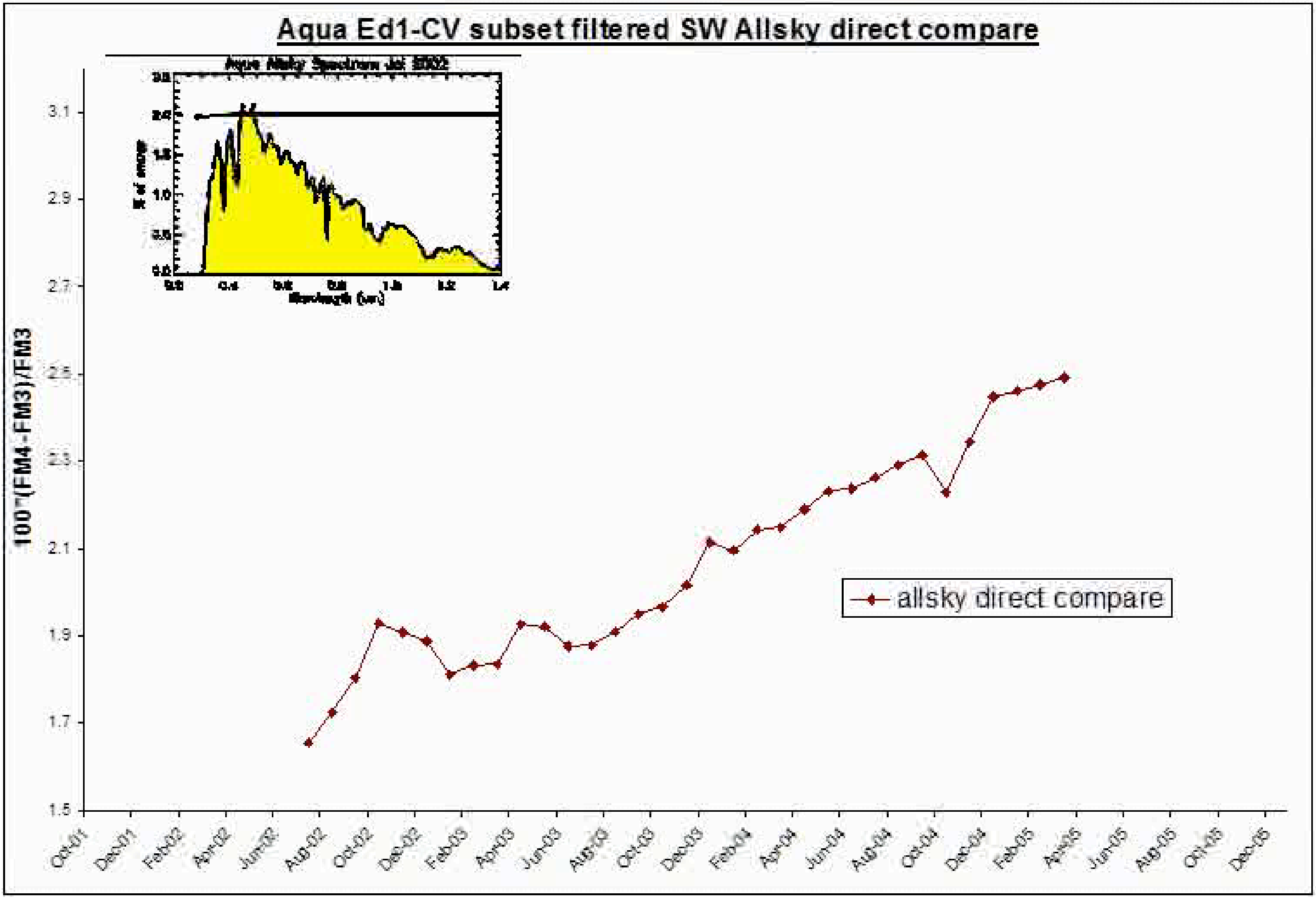
Assuming the deep convective cloud albedo is constant, the change in Aqua gains can be estimated:



Model Tuning: given these Ed3 spectral response and gain changes what would the theoretical direct compare look like:

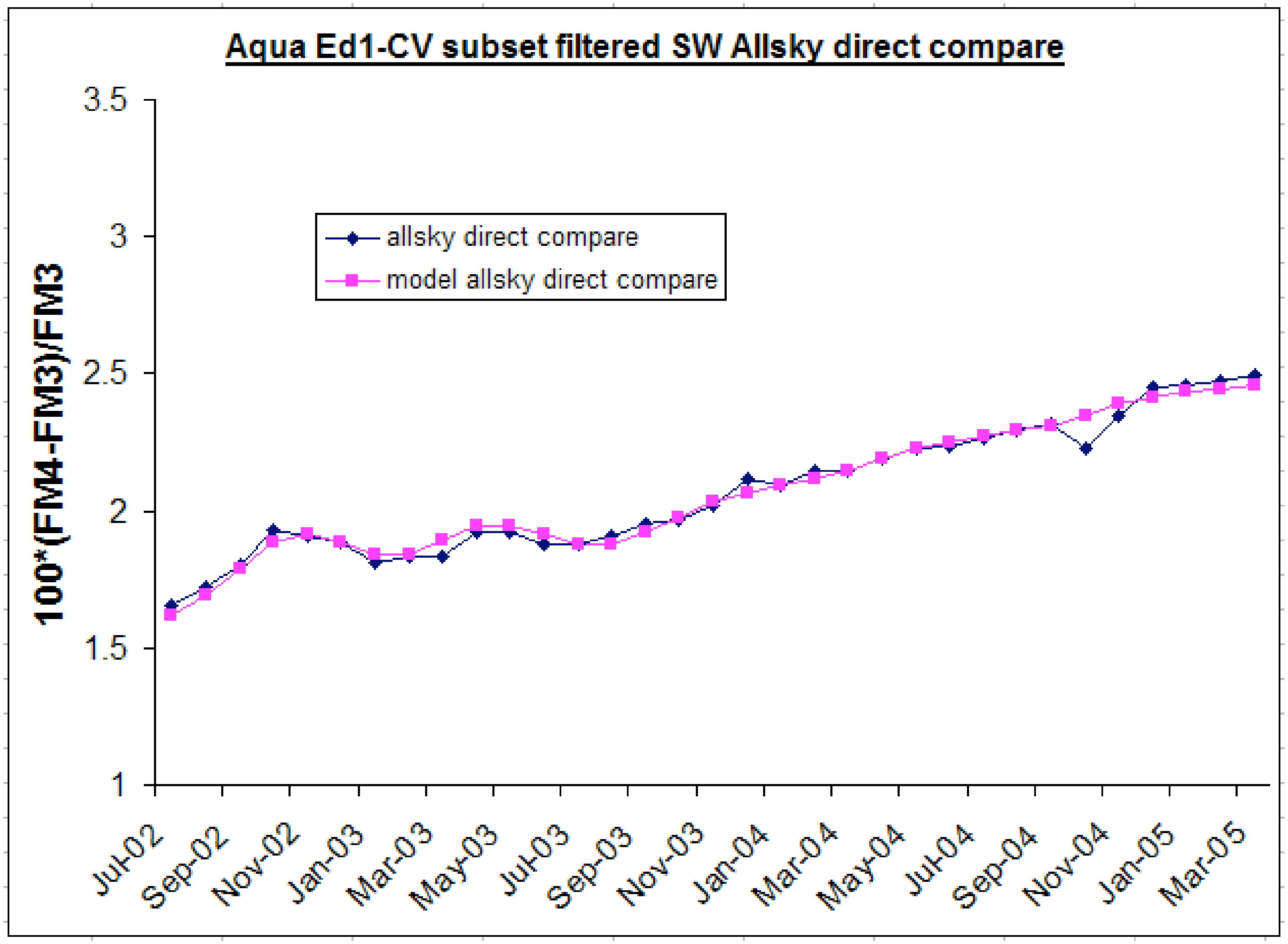
$$DC^{i} = 100\left[\frac{G^{fm4}\int_0^\infty D^{fm4}(\lambda).R_{sw}^{0(fm4)}(\lambda)L^{i}(\lambda)d\lambda}{G^{fm3}\int_0^\infty D^{fm3}(\lambda).R_{sw}^{0(fm3)}(\lambda)L^{i}(\lambda)d\lambda} - 1\right]$$

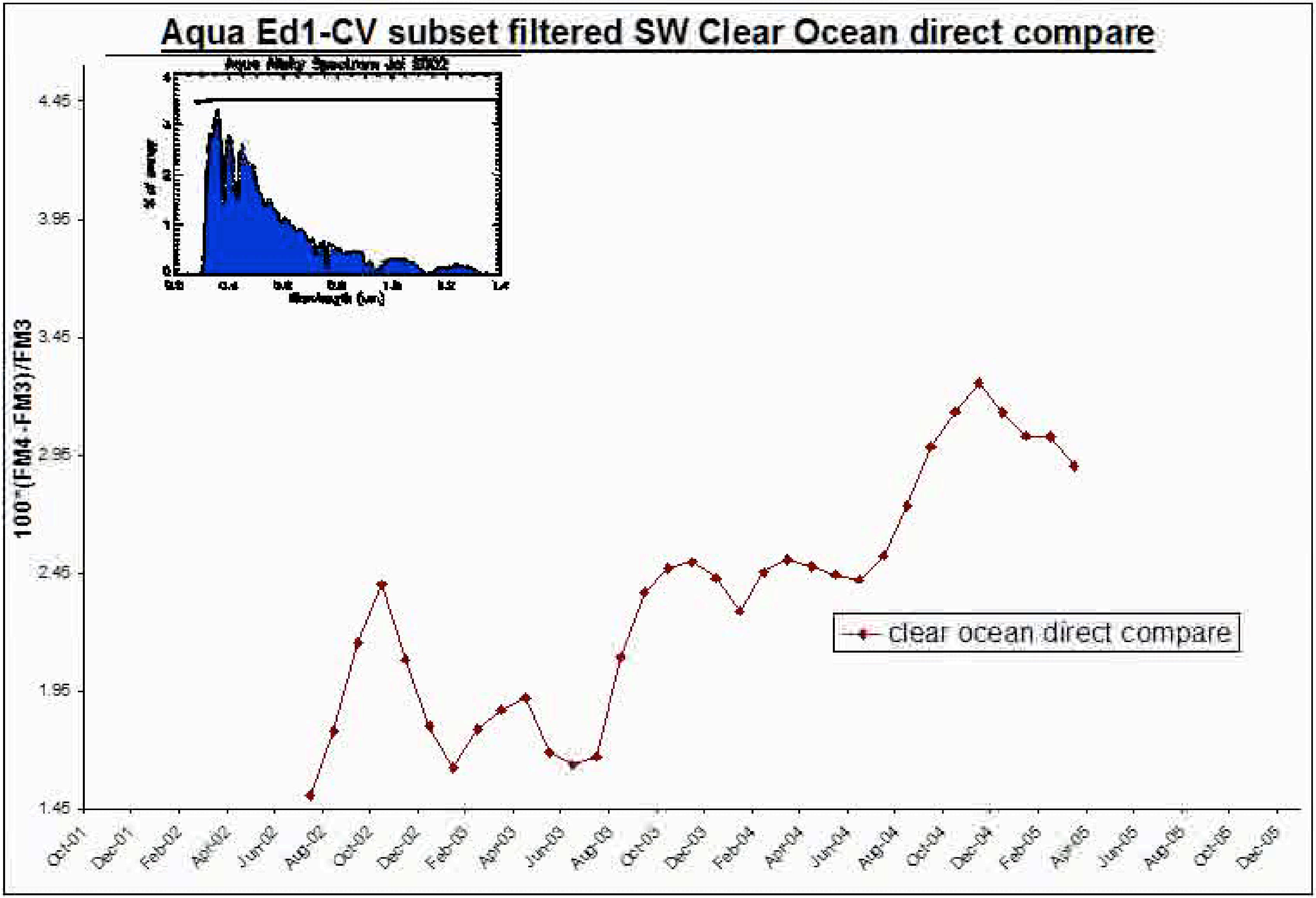
Hence it is this theoretical model estimate that is compared to the actual allsky and clear ocean direct compare and used to tune the model.



Aqua Ed1-CV subset filtered SW Allsky direct compare
100*(FM4-FM3)/FM3
allsky direct compare
Oct-01
Dec-01
Feb-02
Apr-02
Jun-02
Aug-02
Oct-02
Dec-02
Feb-03
Apr-03
Jun-03
Aug-03
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05

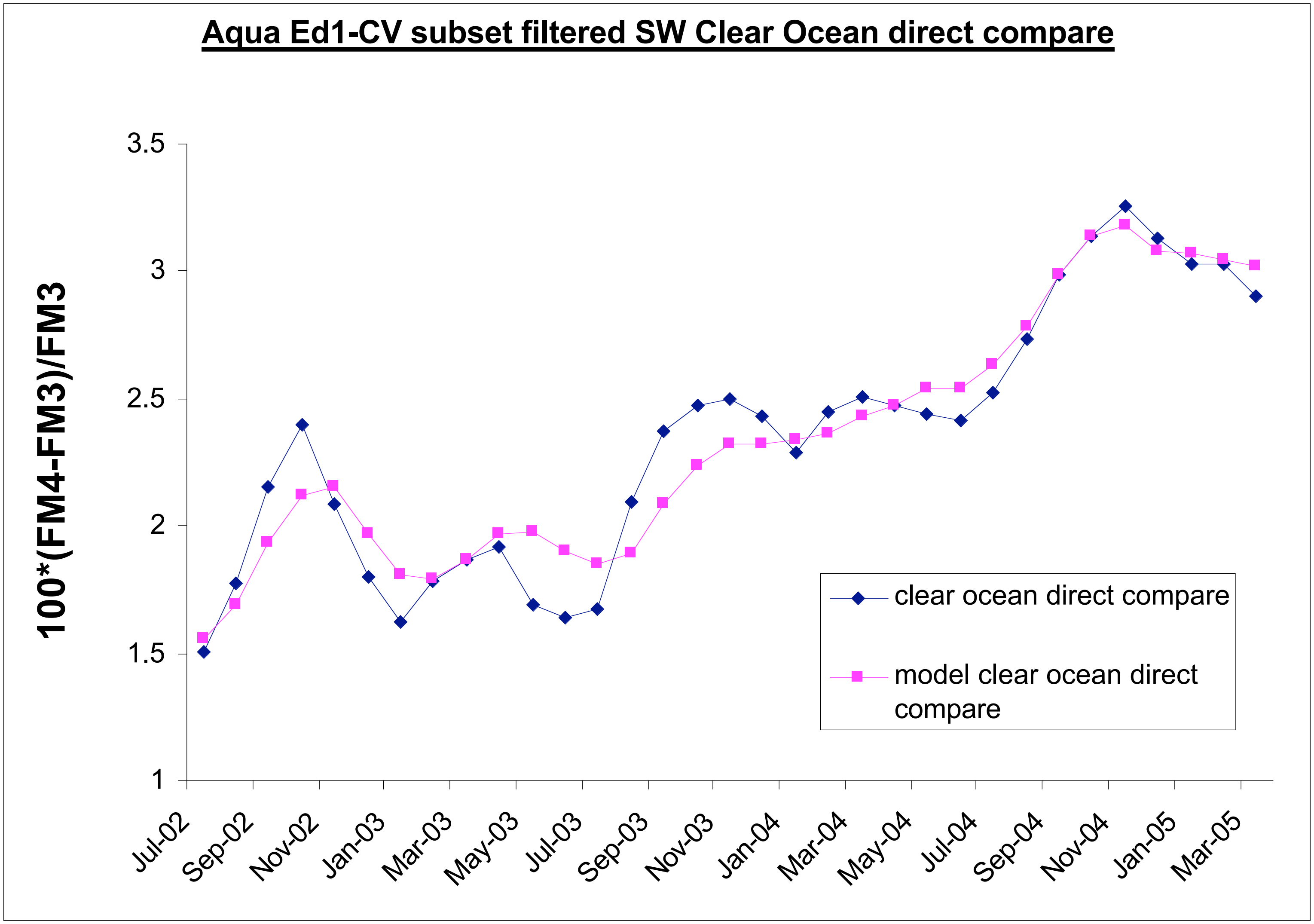
The model is tuned to fit the allsky direct compare:



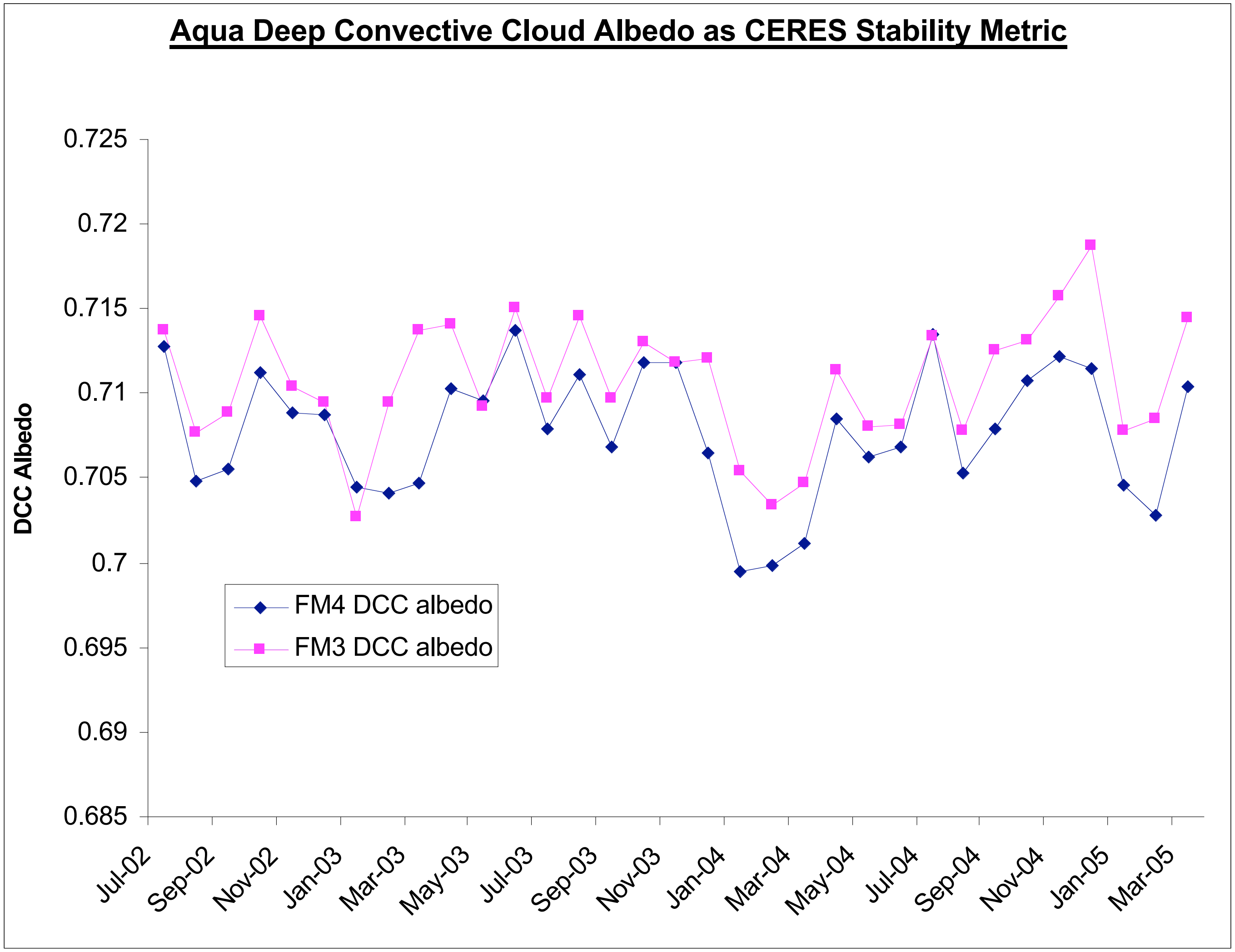


Aqua Ed1-CV subset filtered SW Clear Ocean direct compare
100*(FM4-FM3)/FM3
4.45
3.95
3.45
2.95
2.45
1.95
1.45
Oct-01
Dec-01
Feb-02
Apr-02
Jun-02
Aug-02
Oct-02
Dec-02
Feb-03
Apr-03
Jun-03
Aug-03
Oct-03
Dec-03
Feb-04
Apr-04
Jun-04
Aug-04
Oct-04
Dec-04
Feb-05
Apr-05
Jun-05
Aug-05
Oct-05
Dec-05
clear ocean direct compare

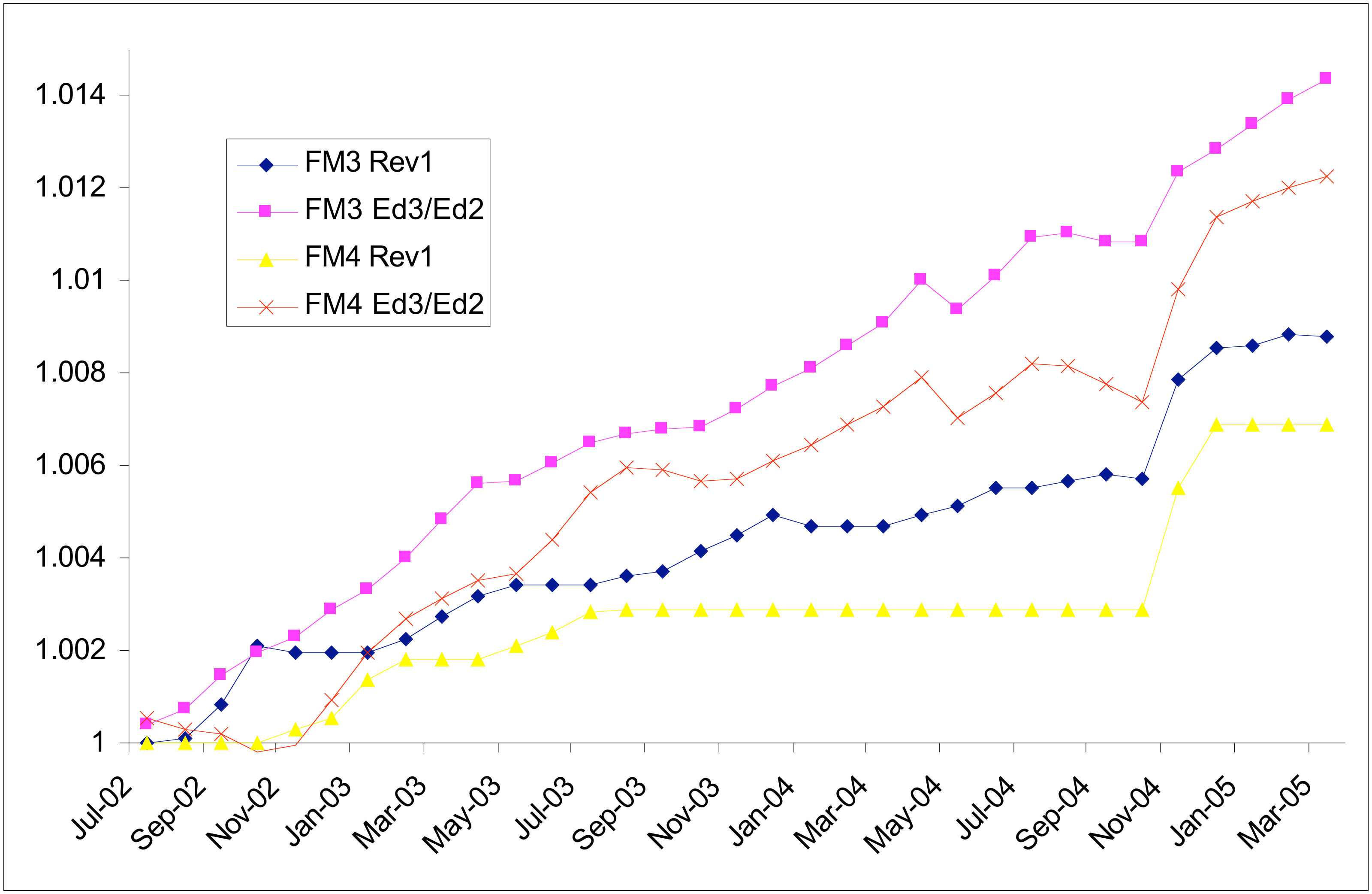
And to a lesser degree (weighted by relative SNR) to clear ocean direct compare:



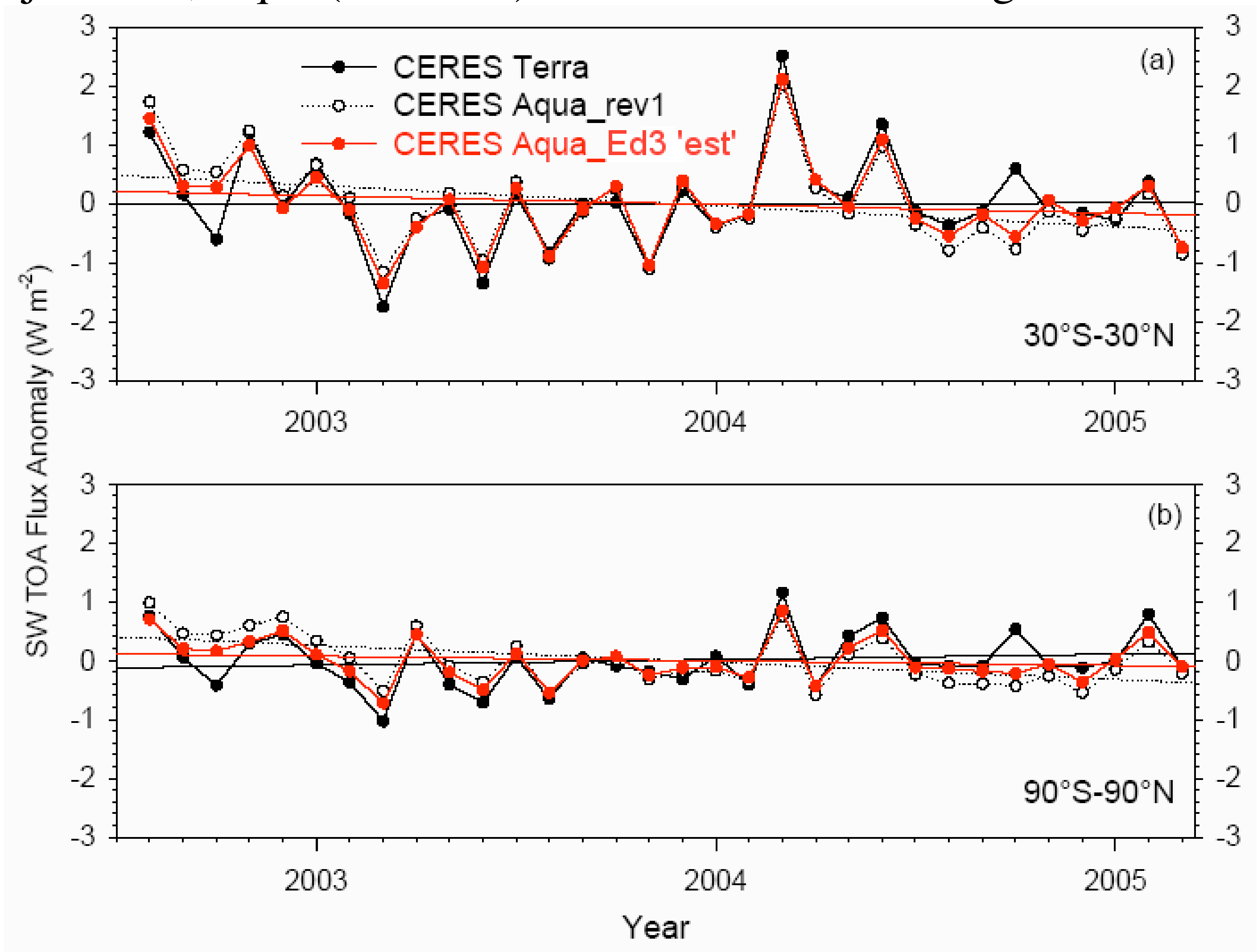
Hence rather than the MAMS, the DCC albedo becomes the metric by which CERES SW stability is obtained:



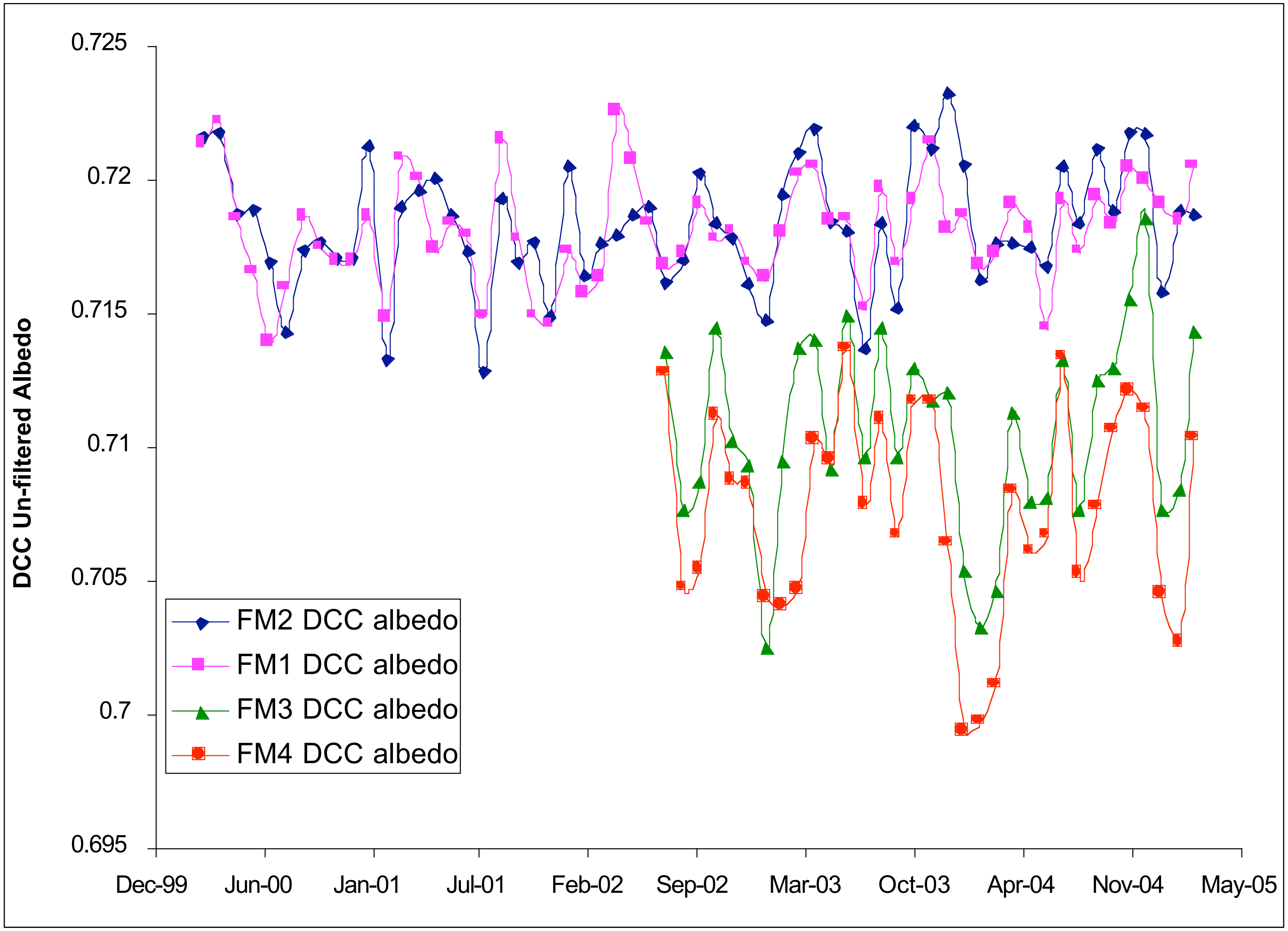
One can estimate the ratio of Ed3/Ed2 Aqua data using these spectral response and gains:



When this estimate of the Aqua Ed3/Ed2 ratio is applied like the Rev1 adjustment, Aqua (Ed3 'est') and Terra reach better agreement



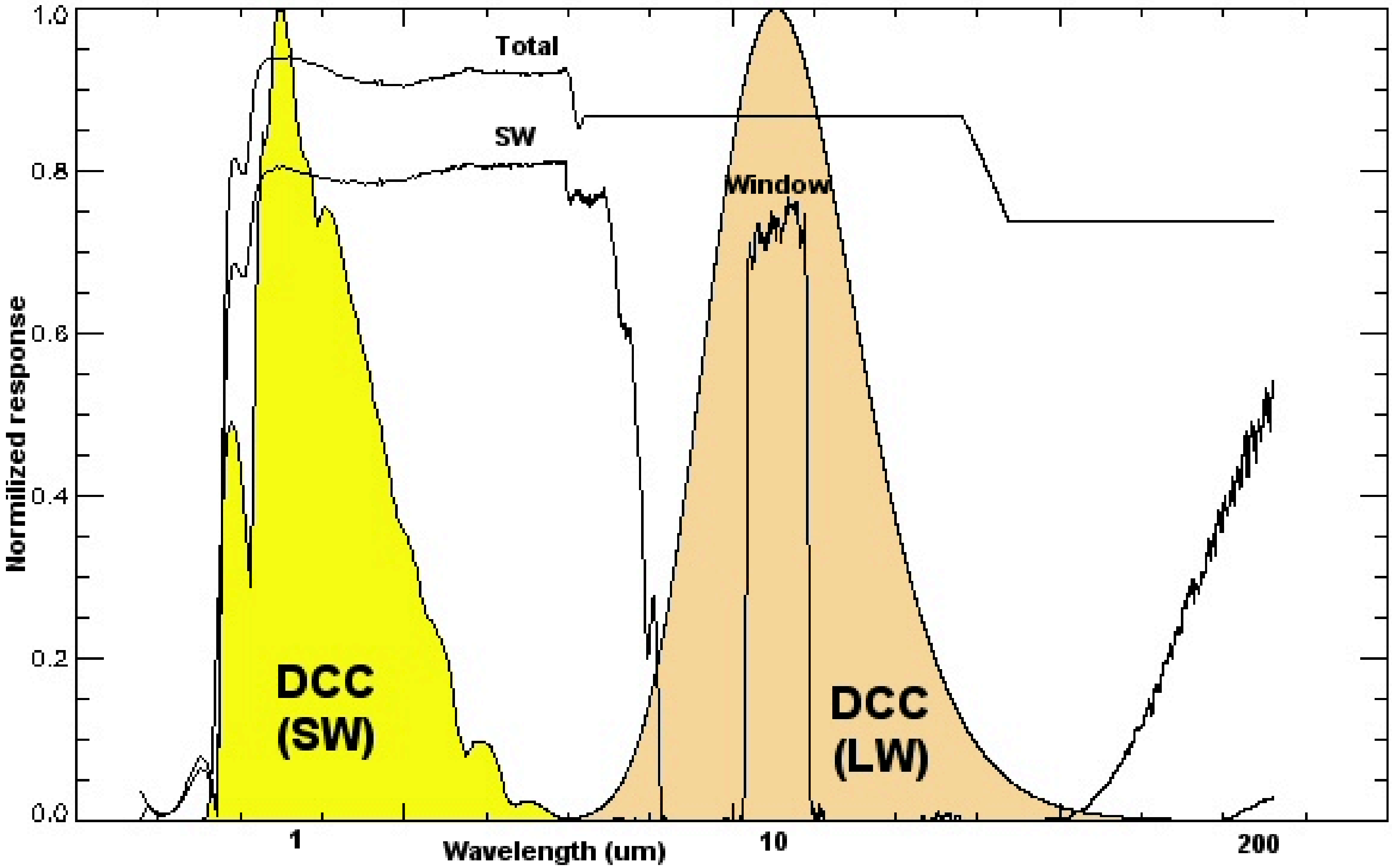
A comparison between Terra and Aqua Ed3 DCC Albedo highlights absolute differences and provides the opportunity to place all measurements on same radiometric scale



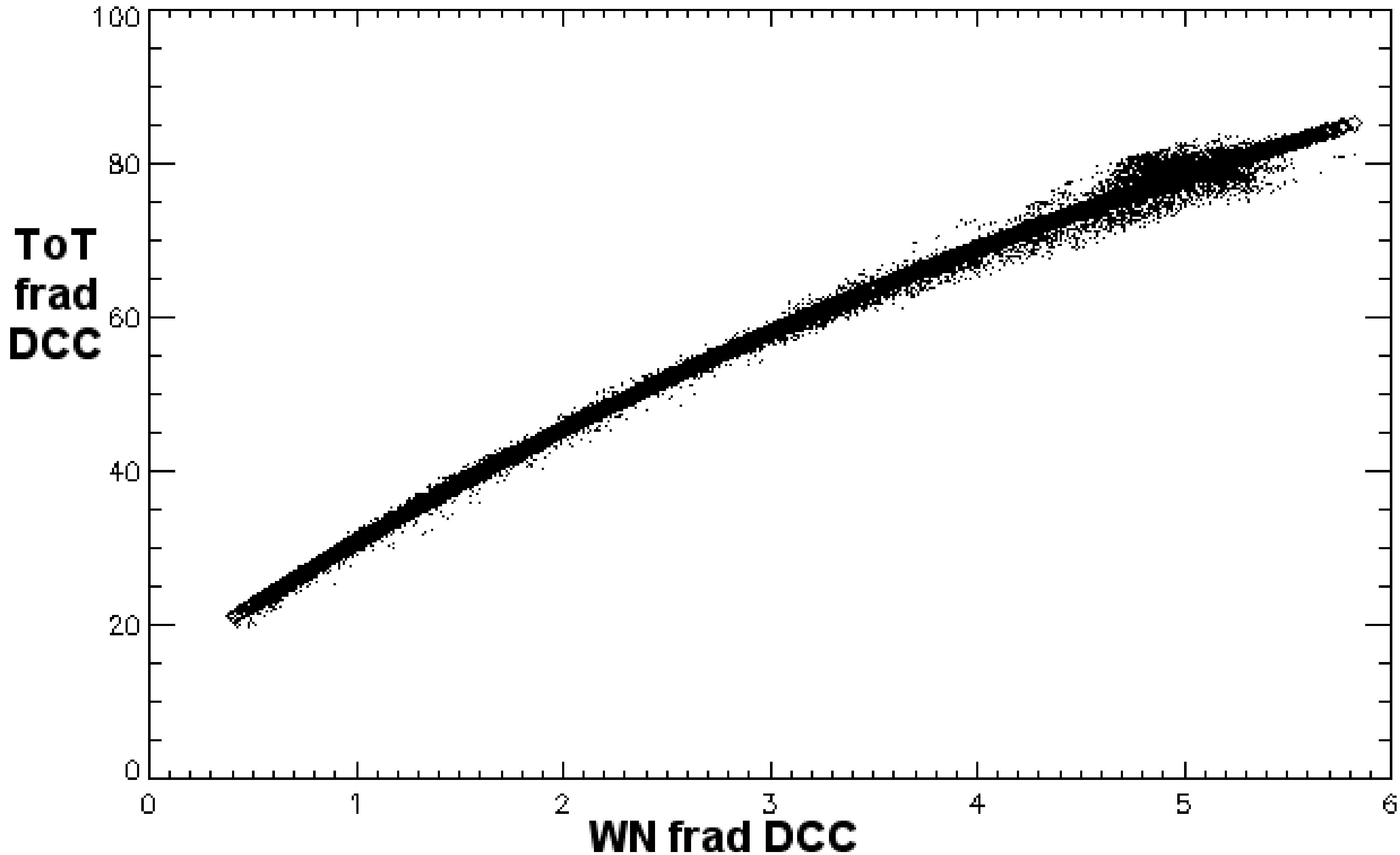
Model Summary

- The new model uses SSF Modis info on the scene and spectrum.
- Lamp data is completely neglected for purposes of stability monitoring
- DCC albedo is used to obtain stability and accuracy while the direct compare is used to obtain precision
- Gain and spectral response are not separable to 0.3%/decade. However Gain*Spectral response within the model may well be

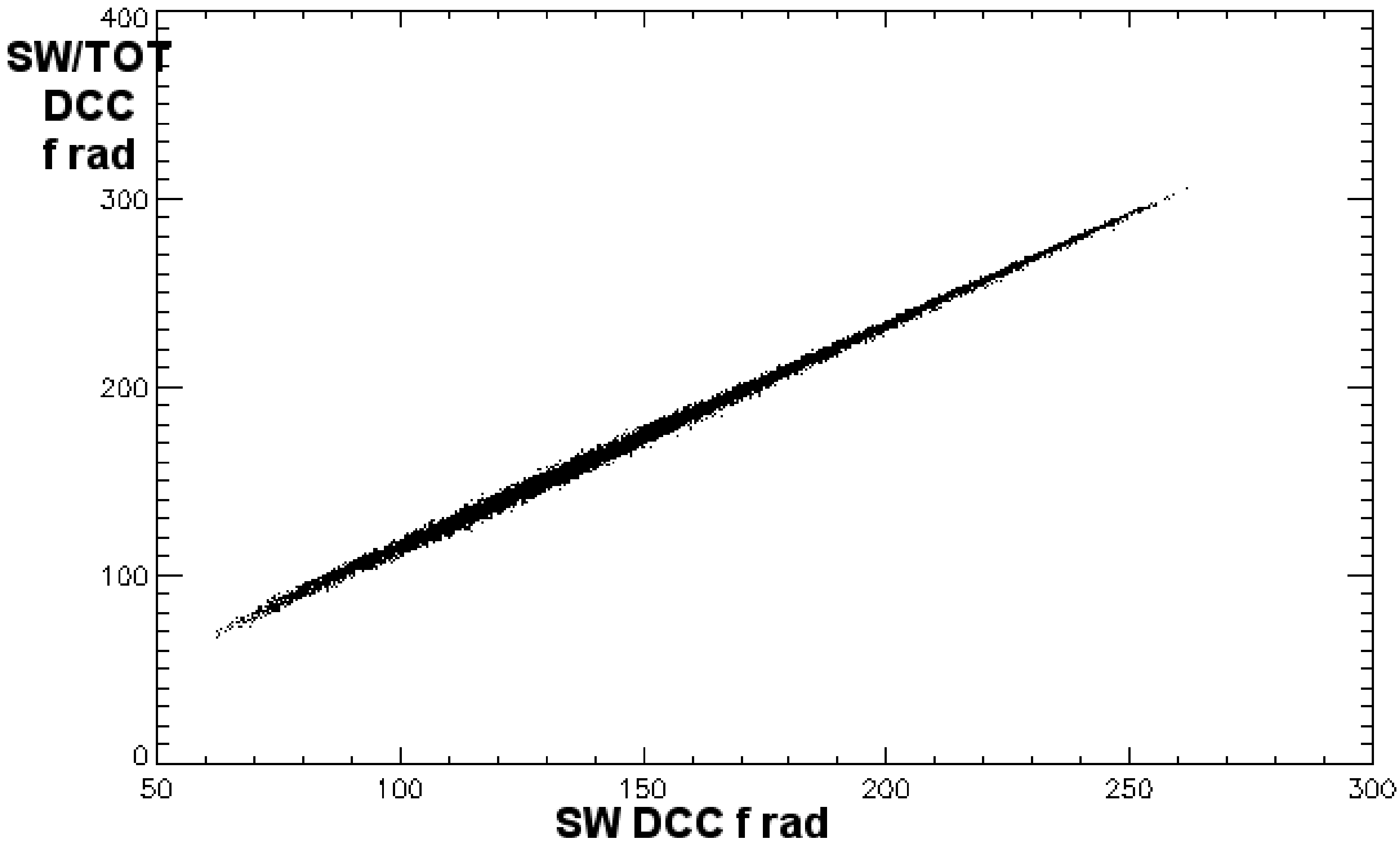
Re-analysis of 3 channel Deep Convective Cloud balancing to determine SW potion of Total channel response



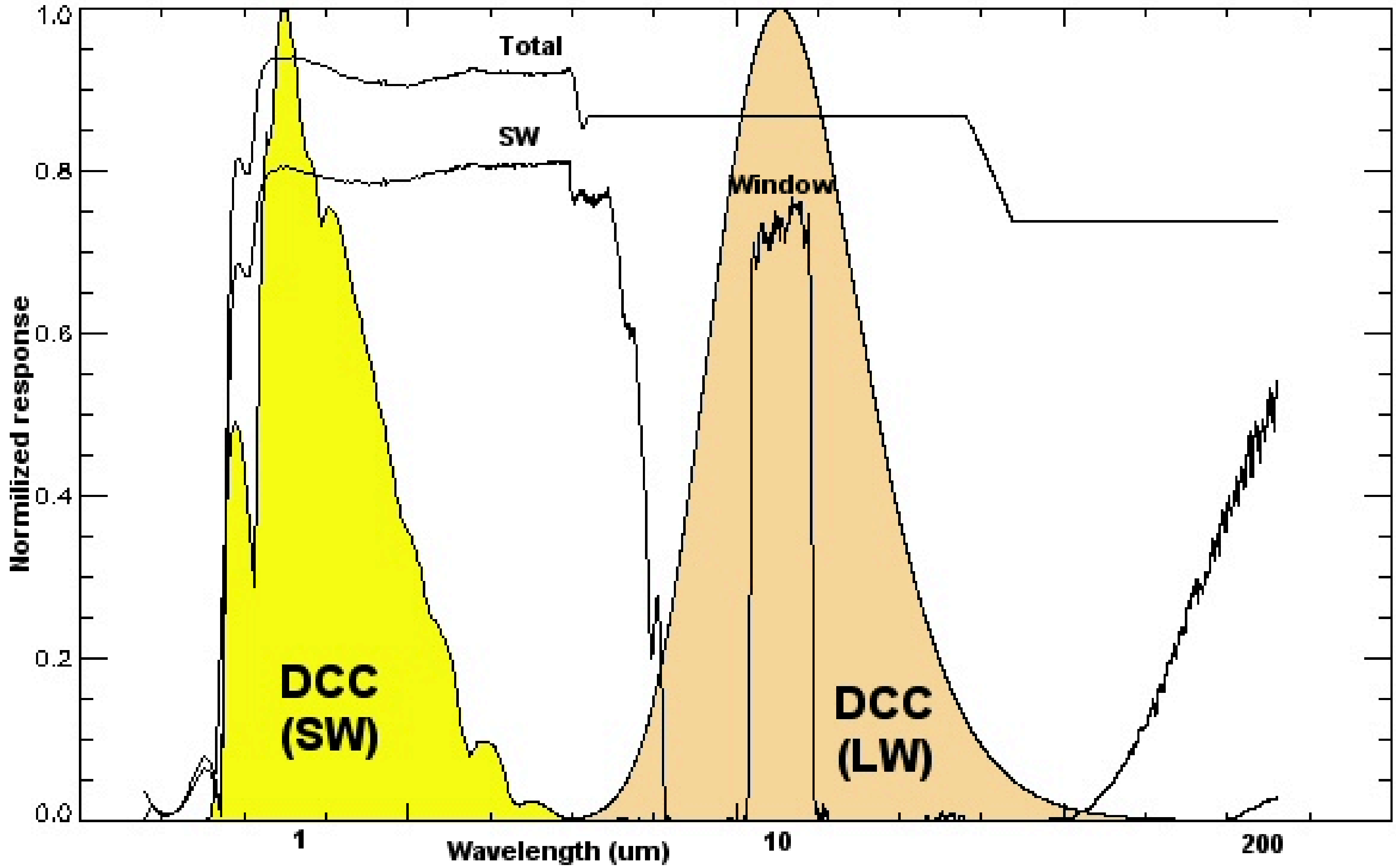
Train window channel on DCC at night



During day use window channel to remove the filtered LW DCC signal from filtered total radiance. Compare Total and SW response to DCC SW radiance:



Re-analysis of 3 channel Deep Convective Cloud balancing to determine SW potion of Total channel response

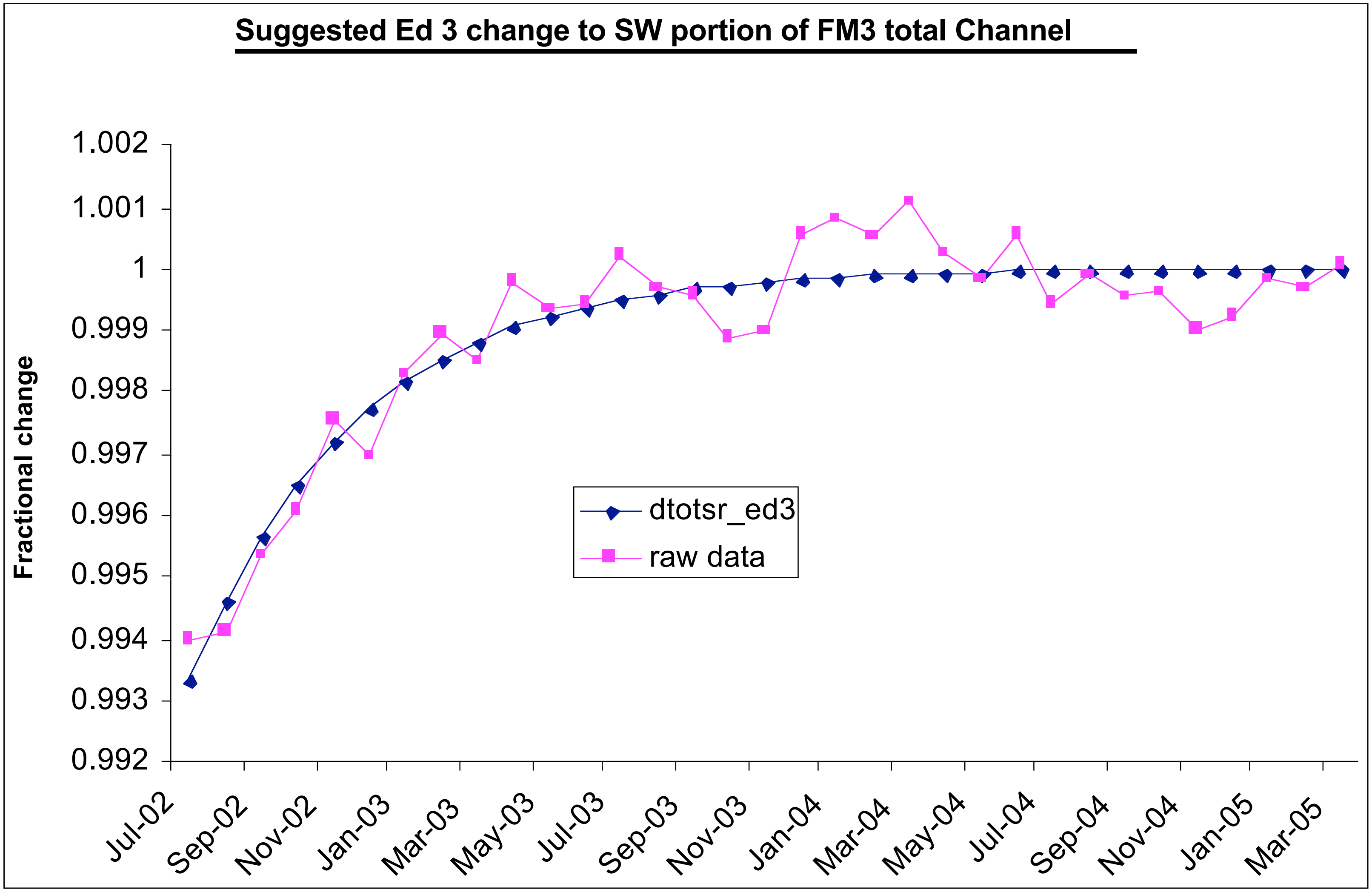


The suggestion is that on the Aqua instruments the SW portion of the Total spectral response needs to be lowered at mission start

$$slope = \Delta TOTSR \times \frac{G^{tot} \int_0^\infty r_{tot}(\lambda) L^{DCC}(\lambda) d\lambda}{G^{sw} \int_0^\infty r_{sw}(\lambda) L^{DCC}(\lambda) d\lambda}$$

This would result in an increase in daytime LW and perhaps a 2 W increase in net OLW flux?

The analysis suggests that the response of both Aqua Total channels rose:



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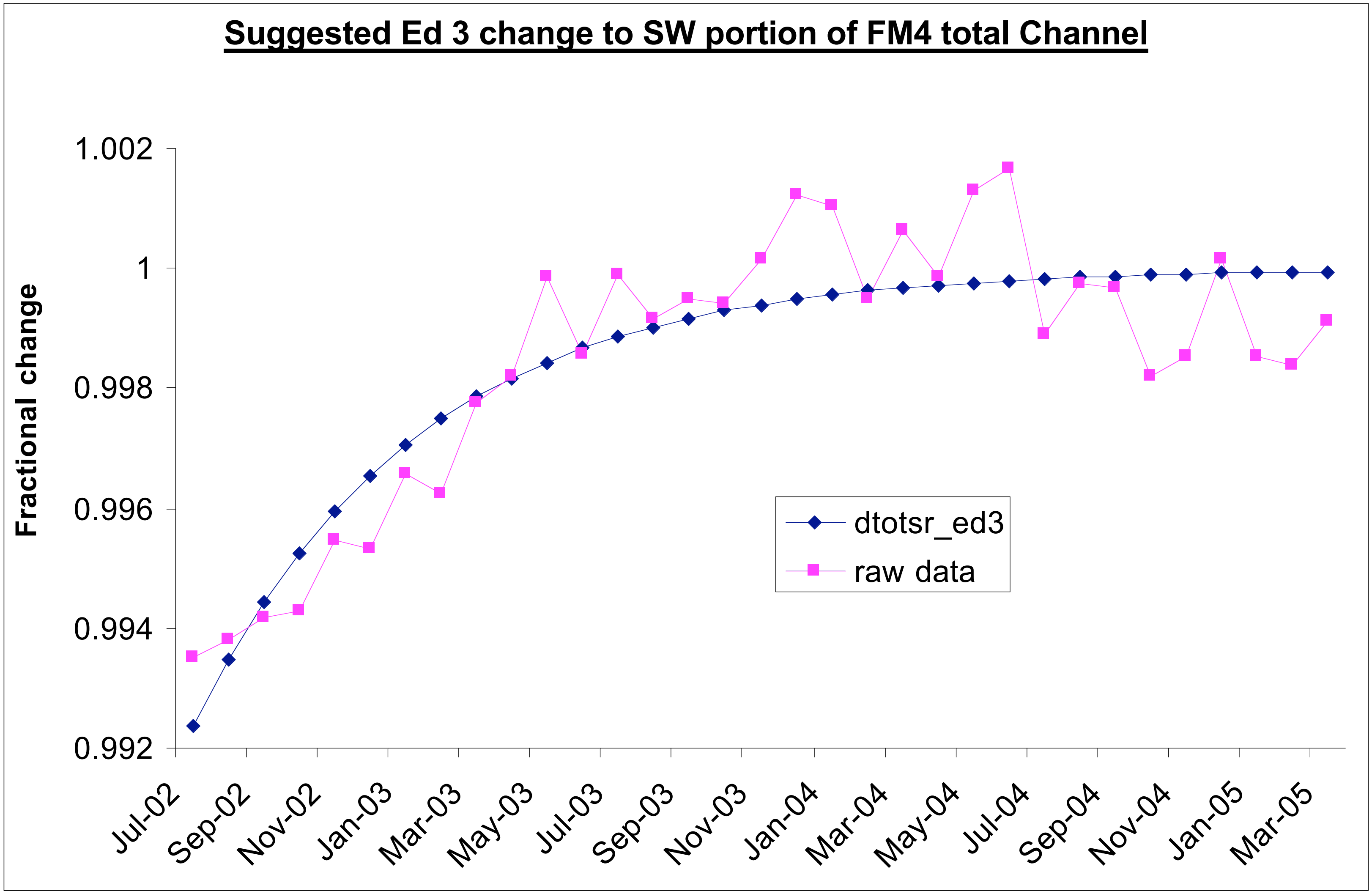
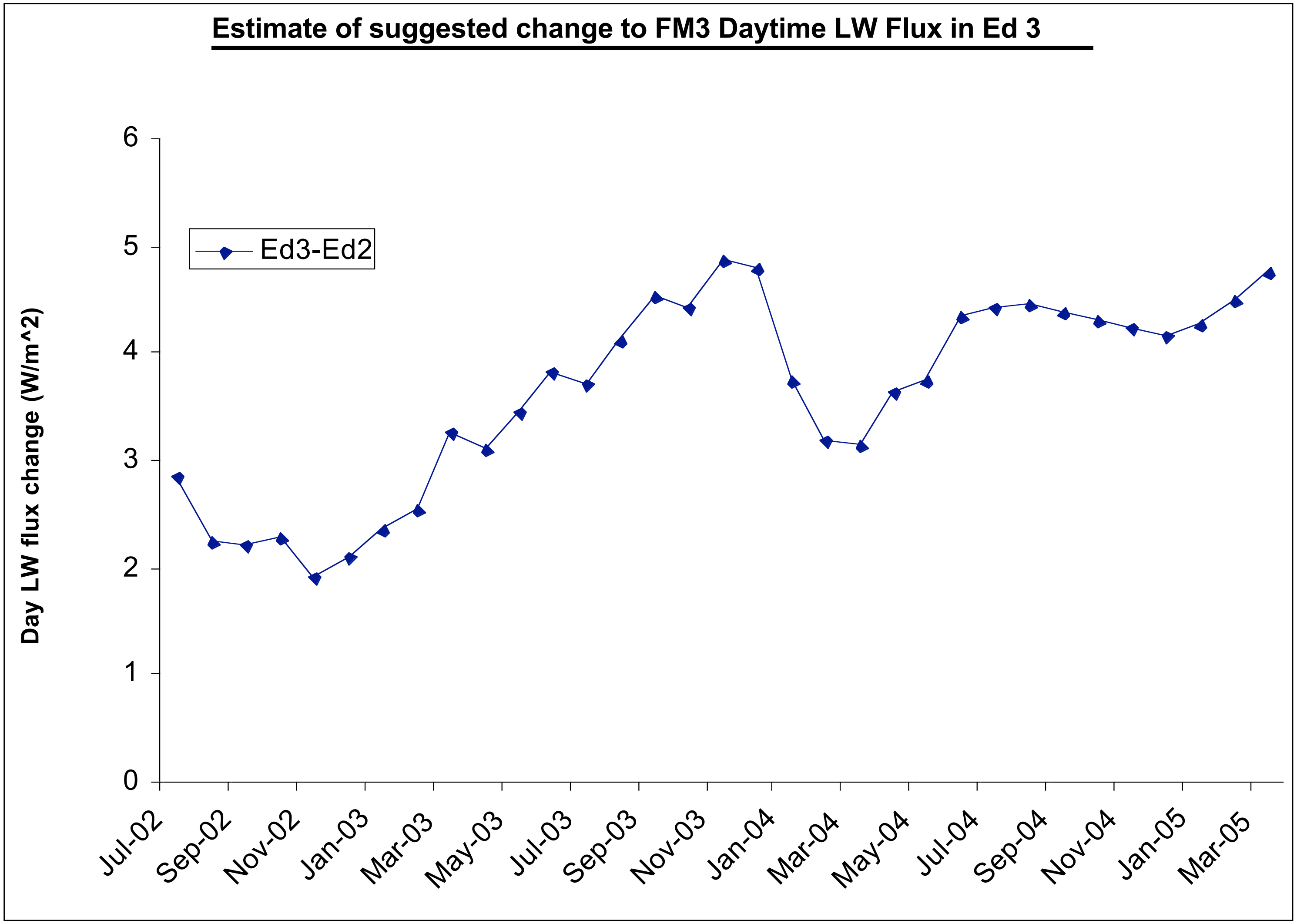


One can then estimate the change in measured Ed 3 daytime LW flux from Ed 2



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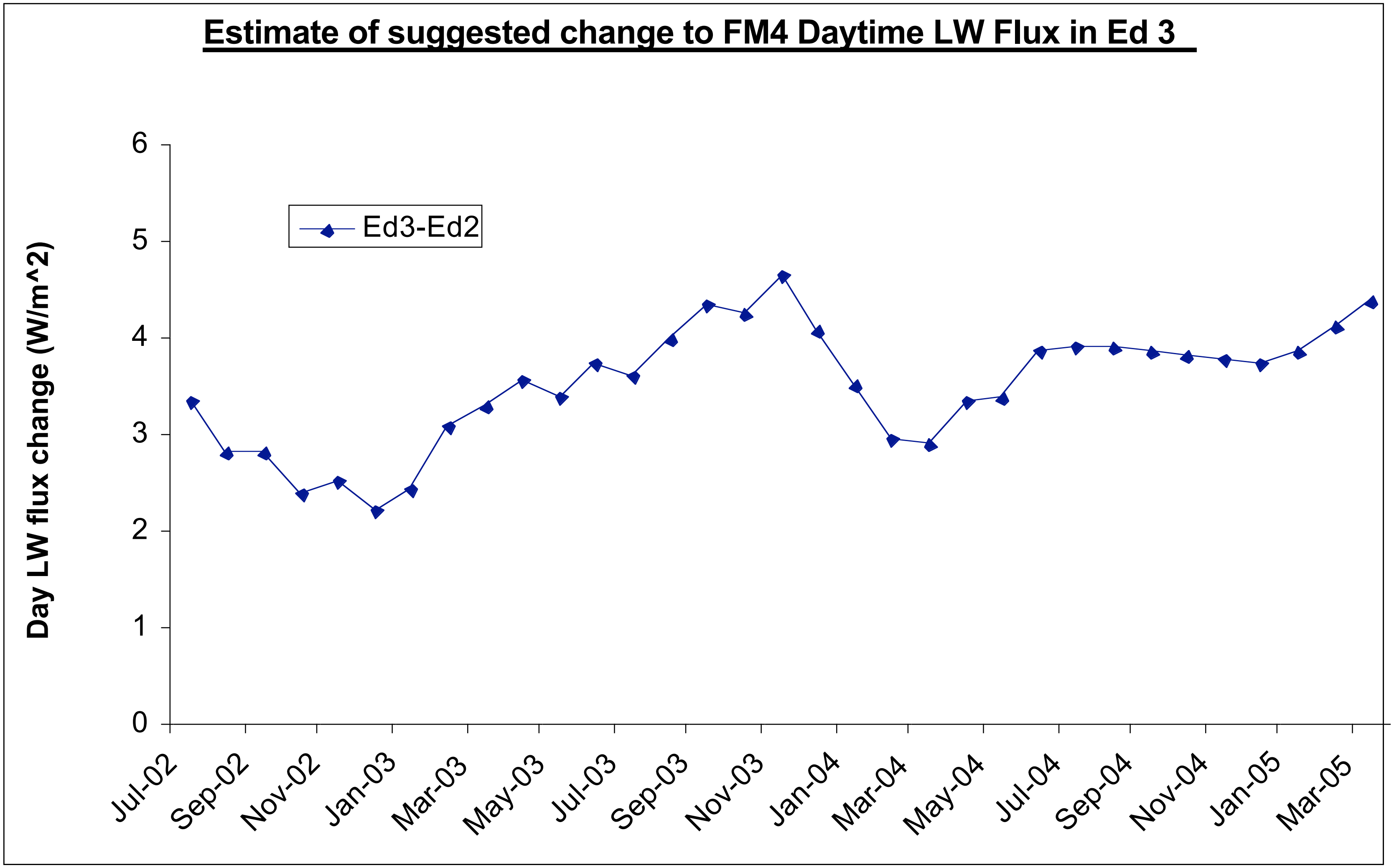
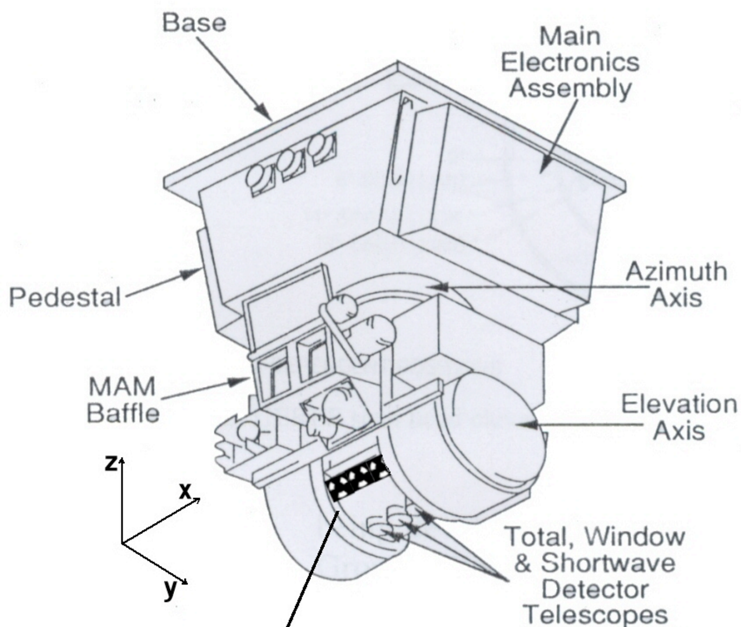
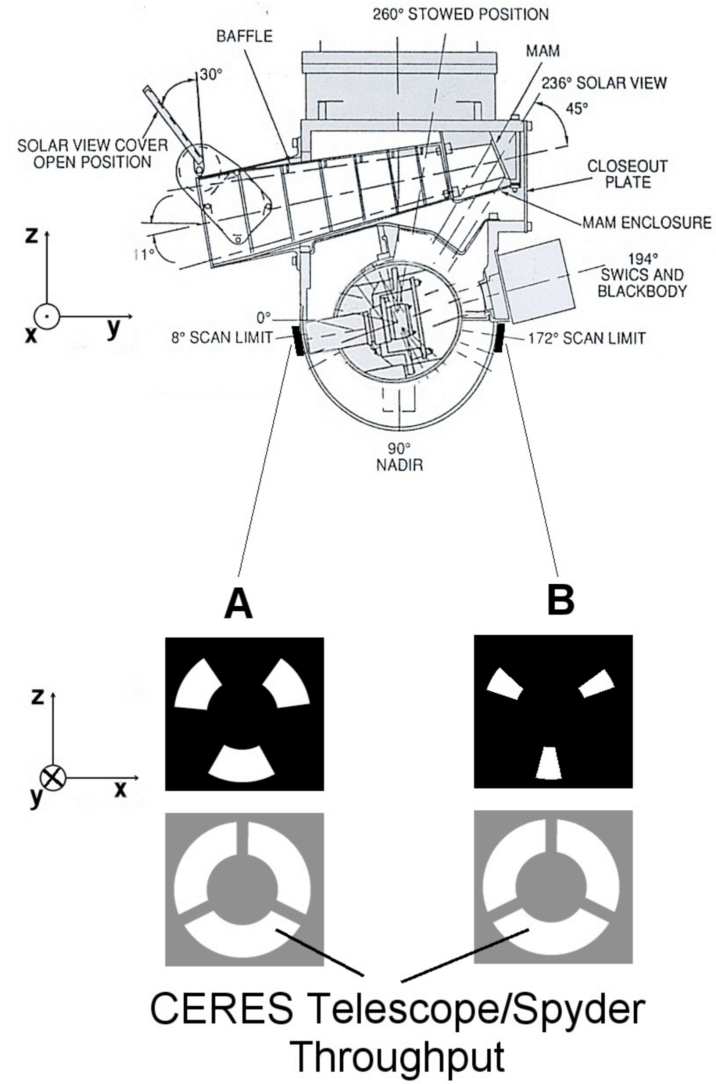


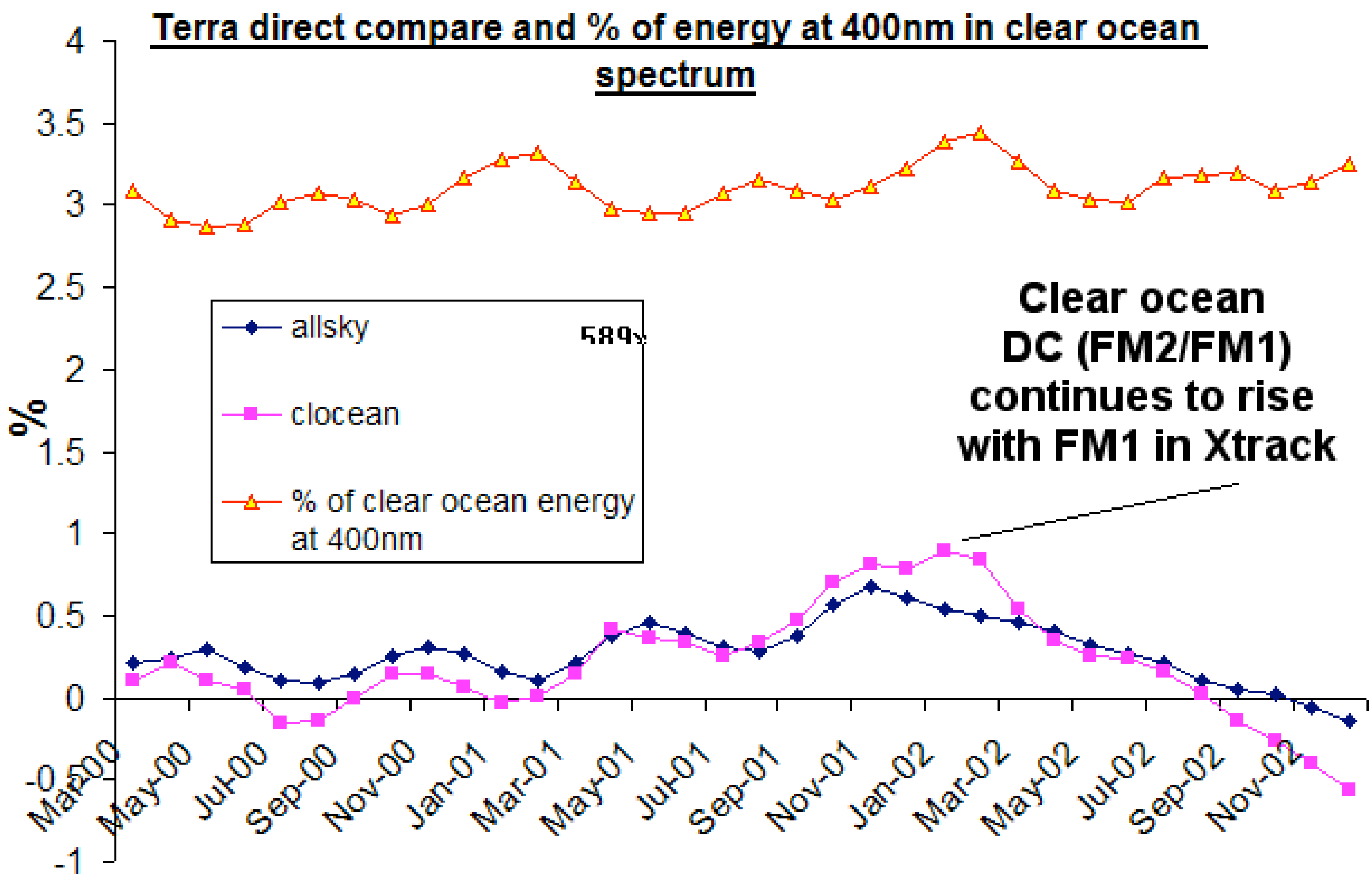
Future considerations and topics for discussion

- New operational constraints restrict ability to look forwards
- Good evidence that CERES Ed2 LW measurements are too low and have negative trends
- Stability of DCC albedo? Confirmation required?
- Use of DCC albedo to place all CERES measurements on same radiometric scale?



Use 'solar calibration masks' with < 50% throughput of CERES telescope to do raster scan of the Sun at sunset




Terra direct compare and % of energy at 400nm in clear ocean spectrum
4
3.5
3
2.5
2
%
1.5
1
0.5
0
-0.5
-1
allsky
clocean
% of clear ocean energy at 400nm
589
Clear ocean DC (FM2/FM1) continues to rise with FM1 in Xtrack
Mar-00
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
May-01
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
Jul-02
Sep-02
Nov-02